THE UNIVERSITY OF ALBERTA

A LOCATION ANALYSIS FOR HOG ASSEMBLY CENTRES IN ALBERTA

by

(C) JAMES L. [illegible]

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF AGRICULTURAL ECONOMICS AND RURAL SOCIOLOGY

EDMONTON, ALBERTA

SPRING, 1971

THE UNIVERSITY OF ALBERTA

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The undersigned certify that they have read and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled "A Location Analysis for Hog Assembly Centres in Alberta," submitted by James L. Dawson in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

To maintain or increase its share of North American and foreign markets, the Alberta hog industry must become increasingly competitive. To do so will require improvements in production and market efficiency. The initiation of the Alberta Hog Producers Marketing Board on November 1, 1969, has provided new opportunities for the improvement of market efficiency.

The focus of this thesis was a subset of market efficiency; namely, to reduce the cost of assembling and transporting hogs from the producer to the packing centre. A long-run spatial model was applied to establish a least-cost solution. This solution suggested the number, the size, and the location of assembly centres that would minimize assembly and transportation costs. Basic data requirements were: a supply analysis for each census subdivision, a demand analysis at packing centres, an operational cost analysis for assembly yards, an analysis of transportation costs, and a road-mileage matrix for Alberta.

The least-cost solution utilized the existing packing centres and selected 51 strategic assembly locations in place of over 300 existing assembly locations in the present system. Suggested average cost-savings for assembly and transportation were about 40 cents per hog. By consolidating the assembly system, the assembler to packer flow of hogs would be more uniform, resulting in cost savings at the processing level.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The Importance of the Pork Industry

The importance of livestock and livestock products in Canada's agricultural sector is at times overlooked. Since 1960, farmers have earned 56 to 62 percent of their income from the livestock industry. In the 1960s, the sale of hogs accounted for 9 to 10 percent of the Canadian farm income every year. Appendix A shows these percentages as well as the value of the hogs sold each year. By comparison, beef provided 22.6 percent and wheat 21.1 percent of the total farm income for 1968 [11]. Cash receipts to farms are only a portion of the revenue produced by the swine industry. In 1965, the total retail value of about 168 million dollars for Alberta pork consisted of approximately 77 million dollars to producers plus 91 million dollars for assembly, processing, and distribution [8]. The unmarketed pork consumed by the farm population can also be considered an indirect form of revenue.

In 1945, Alberta was the largest pork producer in Canada; however, since 1963 this province has ranked third with Quebec second and Ontario first. Table 1 presents the 1960-1969 volume data for Alberta and Canadian swine production. Canadian production volumes and most other aspects of the swine industry have remained relatively unchanged over the past fifteen years. For example, the quantities exported and the per capita consumption of pork are much the same as they were ten years ago. Exports have ranged from 47 to 70 million pounds per year; consumption has varied from a high of 56.7 pounds per capita in 1959 to a low of 46.9 pounds in 1966 (Table 2). In 1969, the per capita consumption of meats

Table 1

ALBERTA AND CANADIAN HOG PRODUCTION VOLUMES, 1960-1969

Year	Canada	Alberta	Alberta's Percentage
1960	6,764,196	1,764,695	26.3
1961	6,448,956	1,658,694	25.7
1962	6,593,945	1,674,177	25.3
1963	6,520,828	1,350,490	20.7
1964	7,281,644	1,554,364	21.3
1965	7,077,126	1,429,677	20.2
1966	6,860,030	1,196,402	17.4
1967	8,186,356	1,407,583	17.2
1968	8,145,147	1,541,046	18.9
1969	7,481,479	1,268,145	17.0

Source: Canada Dominion Bureau of Statistics, Canada Yearbook (Ottawa: DBS, 1960-1969).

Table 2

EXPORT, IMPORT, AND CONSUMPTION DATA FOR 1955-1969

Year	Per Capita Consumption	Output	Exports	Imports
	(lbs.)	(million lbs.)	(million lbs.)	
1955-57 (av.)	47.6	862.7	52.6	0.6
1958	49.4	973.6	63.5	1.7
1959	56.7	1,237.7	70.0	1.4
1960	52.6	988.0	67.7	17.1
1961	50.3	975.4	52.4	41.9
1962	50.1	784.6	47.9	35.6
1963	50.7	981.0	47.4	89.5
1964	51.8	1,060.1	54.0	53.8
1965	47.9	1,006.5	58.0	37.2
1966	46.9	1,014.3	48.5	28.3
1967	53.8	1,181.5	59.1	28.8
1968	53.6	1,181.3	60.8	38.5
1969	51.9	1,134.5	56.6	70.2

Source: Federal Task Force On Agriculture, Canadian Agriculture In The Seventies (Ottawa: Queen's Printer, December 1969), p. 166.

in Canada was 198.8 pounds. Pork consumption was approximately two-thirds that of beef (51.9 pounds and 86.4 pounds respectively). For the past ten years beef and poultry have been the only meat products that have shown increasing per capita consumption rates (Appendix B).

At the present time approximately 157,000 gradings are required weekly in Canada to serve the domestic and U.S. export market [1]. Recent projections of pork demand in Canada state that by 1985 pork production will have to increase 33 percent to meet demand requirements [7]. These projections assume a leveling off or a slight decline in pork consumption in the North American market. If Canadian consumption were to increase to the U.S. consumption level of 66 pounds per capita, demand would expand 58 percent by 1985. Such a change in consumption would require over 15 million marketings in 1985.

The Federal Task Force on Agriculture believes that Canadian consumption of pork will remain close to the present level of 50 pounds per person for the next decade. The Task Force states that the U.S. is our prime outlet for pork exports; however, it is unlikely that Canada can lower market price enough to expand this market. Canada's share of U.S. pork imports has dropped from 27 percent in 1960 to 18 percent in 1968. Meanwhile, U.S. imports from Denmark have almost trebled, and her imports from the Netherlands have doubled. In 1968, U.S. pork import origins were as follows: Canada, 55.5 million pounds; Denmark, 111.9 million pounds; the Netherlands, 82.2 million pounds; Poland, 55.1 million pounds; all other countries, 19.4 million pounds [6]. The loss of our market share of U.S. pork imports to Denmark and the Netherlands is an indication of the need for improved production and marketing efficiency in Canada. To regain a share of the U.S. market we must compete more effectively with producers

both in the U.S. and in other countries.

Much emphasis is currently placed on the market potential for pork in Japan. Observing export statistics for the past decade (Table 3), we can derive few conclusions about future pork sales to Japan. Japanese consumption of pork has increased from 7 to 11 pounds per capita since 1960 [15]. Through the use of more specialized production units, Japan has increased production from 142,000 tons in 1957 to 386,000 tons in 1965 [13]. The future market for pork in Japan depends largely upon strategic decisions regarding resource use, trade, and investment in that country.

The largest importers of pork are the European Economic Community (EEC), the United Kingdom, and the United States (Table 4); Denmark and the Netherlands are the largest exporters. Export figures for 1985 are projected in research performed by the Organization for Economic Cooperation and Development [12]. Their study indicates that North America will have no net trade, the Netherlands and Ireland will increase exports similar to present trends, and Denmark will become more competitive. It is predicted that Japan will become self-sufficient. If these projections are correct, the future of Canada's pork industry in the world market depends largely on how well our production and marketing systems can compete with those of Denmark and the Netherlands.

Problem Setting of the Study

Prior to the formation of the Alberta Hog Producers Marketing Board* on November 1, 1969, many discrepancies existed in the pricing and handling mechanisms of the Alberta hog market. In 1967, Manning identified

*The Alberta Hog Producers Marketing Board will henceforth be referred to as "The Board."

Table 3

JAPANESE PORK IMPORTS FROM CANADA, 1960-1969

Year	(pounds)	($ value)
1960	6,765,106	749,324
1961	450,738	151,493
1962	1,082,418	231,041
1963	222,008	46,010
1964	20,300	10,102
1965	-	-
1966	54,198	10,387
1967	-	-
1968	710,324	274,161
1969	4,253,300	2,984,734

Imports From All Countries (million pounds)	
1961-65 (av.)	5.8
1966	1.3
1967	1.5
1968	24.5

Sources: USDA, World Agricultural Production and Trade Statistical Report (Washington, D.C.: USDA, October 1969), p. 6.

Canada Department of Trade and Commerce, Official Reports (Ottawa: Queen's Printer, 1960-1969).

Table 4

CANADIAN IMPORTS AND EXPORTS, 1968-1969

		1968 (lbs.)	1969 (lbs.)
Imports	Country of Origin		
	United Kingdom	948,800	1,562,900
	United States	36,395,100	66,901,750
	Other Countries	207,400	1,279,169
	Total Imports	37,551,300	69,743,819
Exports	Destination		
	United Kingdom	778,000	Included in other countries
	United States	53,419,244	47,693,182
	Other Countries	5,820,000	5,952,500
	Total Exports	60,017,244	53,645,682

Source: Canada Department of Agriculture, Fiftieth Annual Livestock Market Review (Ottawa: CDA, 1969), pp. 12-13.

several factors which added to the cost of marketing hogs [9]. Some of these factors were: (1) excessive duplication of assembly facilities, (2) excessive handling of hogs instead of direct shipments, (3) excess slaughtering and processing capacities, (4) failure of packer procurement charges to reflect procurement costs, (5) a balance of power in the market favoring large retailers, and (6) an inadequate pricing system. Manning estimated that both producers and consumers could benefit from a more equitable distribution of market power. From 50 cents to a dollar per hundredweight could be saved as a result of lower marketing margins [10]. Potential gains from a more competitive pricing system could range from 25 to 50 cents per hundredweight. Manning also estimated that marketing costs at the assembly level could be reduced as much as 50 cents per hundredweight if the assembly system were revised [10].

The Board has remodeled the pricing system, and packers are no longer responsible for procurement charges. However, many of the above-mentioned problems still exist. There is considerable duplication of assembly facilities, packers must operate with excess capacity to accommodate the uneven flow of slaughter hogs, and the balance of market power still remains in the hands of the retailer. A primary goal of the market system should be to move hogs as rapidly and as efficiently as possible from the producer to the packer while maintaining an equitable pricing system. Such a goal also should consider the needs of the packers by providing a more uniform flow of hogs.

Objectives of the Study

The objectives of this study were: (1) to determine assembly costs as a function of the number of hog assembly locations; (2) to determine transportation costs as a function of the number of hog assembly locations;

and (3) to determine the optimum number, size, and location of hog assembly locations in Alberta based on the information established under the first two objectives.

It was anticipated that by properly locating larger volume hog assembly facilities, the average service and transportation cost could be reduced. With fewer assemblers the possibility of regulating the daily and weekly flow of hogs to packers would increase. An efficient marketing system would assure that some of the benefits derived from greater utilization of assembly and packing facilities could be passed on to producers and/or consumers. Through such changes in market performance the industry's competitive position might improve as a result of lower marketing and processing costs. These cost reductions could be a prime means of expanding our domestic and export markets. The benefits from any improvement in pork sales could result in additional returns to every party involved in the market channel, as well as to any suppliers in the industry.

Data Sources

Five basic sets of information were required for the study: regional hog production data, demand for hogs at major packing centres, assembler volumes, transportation costs, and assembly costs. The regional production data and assembler volumes were obtained from information recorded directly from hog manifests for 1967 and 1968 by researchers employed by The Board. Figures for the demand analysis were acquired from reports by the Livestock Marketing Board, Canada Department of Agriculture. Transportation rates for hogs were obtained from confidential industry sources, and data for assembly costs were acquired from annual reports of livestock cooperatives in Alberta for 1968 and 1969. Other information was obtained from the Economics Division, Alberta Department of Agriculture, The Board, and

personal interviews.

Analytical Procedure

Seven basic steps were required to estimate the least-cost solution for location, number, and size of assembly locations in Alberta:

(1) Demand and supply locations were designated and their respective volumes recorded. The principal meat packing centres for Alberta were used as demand centres. Since Lethbridge and other locations had relatively small slaughter volumes, only Edmonton, Red Deer, and Calgary were used as demand centres. The volumes used at the three demand locations included all hogs handled by assemblers. Census subdivisions (counties, municipal districts, and improvement districts) in the hog producing areas of the province were used as supply locations. Volumes shipped by assemblers were recorded for each of these subdivisions.

(2) Potential assembly locations were selected for each subdivision. The two objectives governing this selection were: (i) to choose towns near the centre of each subdivision, and (ii) to choose larger towns with established assembly volumes. The potential assembly locations also are referred to as supply reference points for each census subdivision.

(3) The third step was the development of a transportation matrix for the province. Road mileages between every potential assembly site and supply reference point and transportation rates per mile for shipping hogs by truck were needed. To complete the transportation matrix, volumes from each supply reference point were multiplied by transportation rates and mileages to each potential assembly location. The result was a 60 x 60 transportation matrix for Alberta.

(4) Analysis of assembly costs was necessary to establish a cost-to-volume relationship. Formulas were developed to consider the fixed costs

plus the variable costs per hog assembled.

(5) Transportation costs from supply reference points to assembly sites were added to assembly costs to derive the combined cost function with respect to the number of assembly locations.

(6) The assembler to packing centre transportation cost was calculated with respect to assembly location numbers. This transportation cost was added to the combined cost function for each number of assembly locations to compile the total combined cost function.

(7) The final step delineated the least-cost solution, which was represented by the minimum point on the total combined cost function.* The solution stated the number, location, and volume of each assembly location. The solution also indicated to which assembly location producers should ship and to which packing centre each assembly location should deliver hogs so that distribution costs could be minimized.

A computerized solution procedure for the long-run spatial model was used to calculate assembly and transportation costs from supply reference points to assembly locations. Assembly to packing centre transportation costs were calculated with the linear programming transportation model.

*Combined cost function (CC) refers to the summation of assembly costs and transportation costs from supply reference points to assembly locations. The total combined cost function (TCC) refers to the combined cost function plus transportation costs from assemblers to packing centres.

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CHAPTER II

PERSPECTIVE AND A PROBLEM DIAGNOSIS IN THE ALBERTA PORK INDUSTRY

Production Organization

The Alberta pork industry requires growth in domestic and export markets if it is to remain viable. Although the demand for pork is expected to increase with population growth, an increase in per capita consumption and/or an increase in exports is necessary to stimulate growth in the industry.

Larger markets may be attained through product promotion and quality improvement programs. For every hog* marketed in this province, The Board deducts five cents to be used for purposes of research and promotion. By creating a more impressive image for pork, the Board may lower the price elasticity and increase the income elasticity for the product. In 1964, Holmes estimated the income elasticity of pork to be .10 and beef to be .15 [13]. An income elasticity of .10 for pork means that for each dollar that incomes increase (decrease), ten cents more (less) will be spent for pork. In Holmes's study estimated price elasticities in 1964 were -1.69 for pork and -.77 for beef. The lower price elasticity for pork indicates that as a result of a price increase or decrease, the quantity of pork demanded will decrease or increase more than the quantity of beef demanded. Holmes estimated the cross elasticity of pork with respect to beef prices to be .59 and the cross elasticity of beef with respect to pork prices, .09. Such elasticities indicate that pork is

*Throughout this study the term "hog" will refer to all swine sold for slaughter purposes.

used as a substitute for beef when beef prices are high; however, beef does not serve as a substitute for pork when pork prices are high.

Canadian grading systems and bonuses have created incentives for the production of quality hogs. On January 1, 1969, a new index grading system was adopted. Previously, hogs were graded according to weight, carcass length, and shoulder and loin fat. The acceptable specifications permitted more fat than the present system of grading, and there was overlap of grades. The new system is designed to increase the incentive for production of lean hogs. Carcass quality is based upon the percentage of lean, which is determined by the weight of the carcass and the depth of shoulder and loin fat. Utilizing the depth and weight measurements, an average hog (index = 100) may have a total backfat range of 3.2 to 3.3 inches and a carcass weight of 150 to 159 pounds. Producers receive a $1.50 government premium for hogs that index 105 or higher. The premium creates a double incentive to the producer since the price received also increases progressively as the quality index increases above 100 [7]. On December 31, 1970, the government premium will be discontinued. Hawkins has noted that at times when hog prices are nearing the peak of the cycle, high quality hogs may be discriminated against by purchasers because the price spread between higher and lower indexes tends to become more extreme [12]. Details for both grading systems are presented in Appendix C.

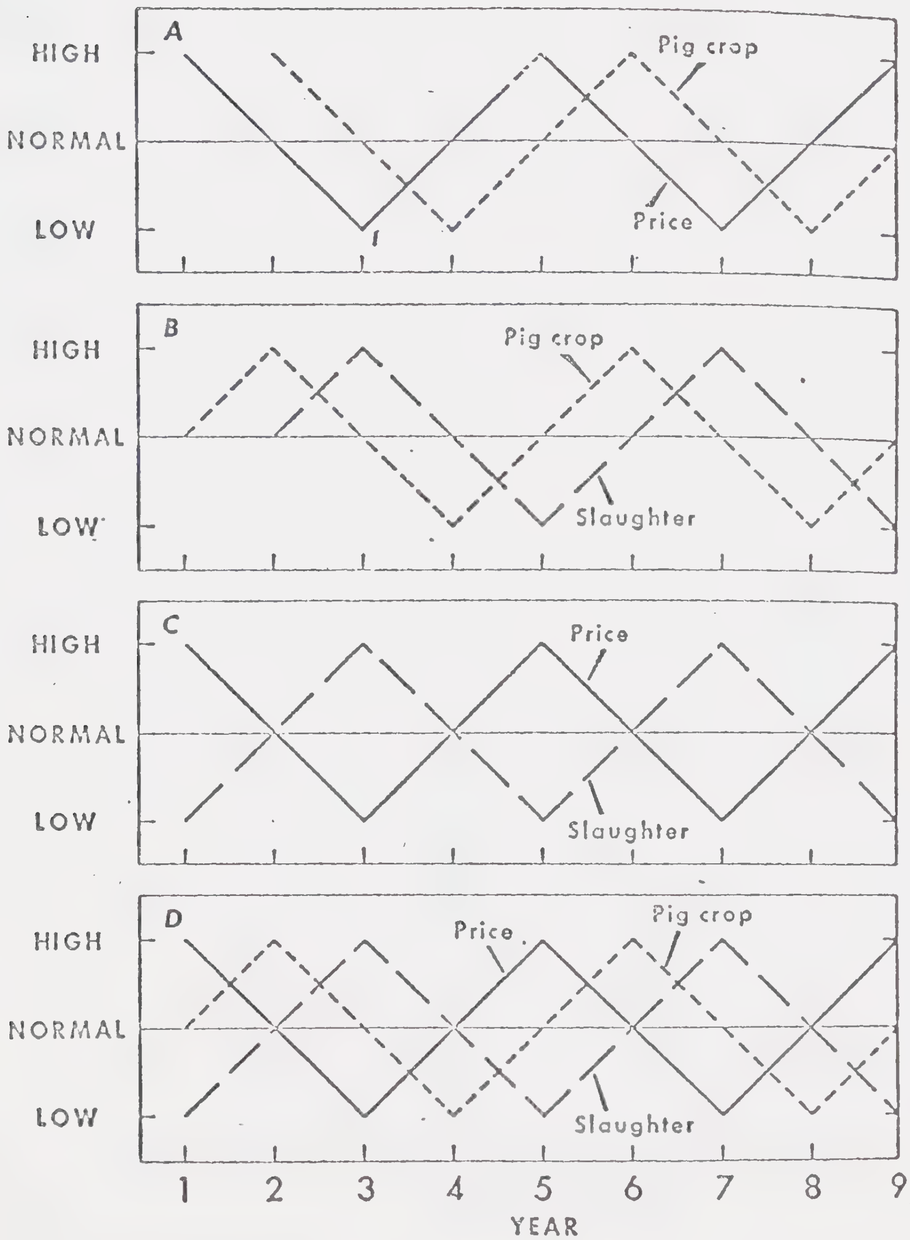
Cycles have existed in hog production for many years. These cycles result from production flexibility in the swine industry. The relatively low capital investment required for a small hog operation enables farmers to move in or out of production easily. The short gestation period and prolificacy of brood sows permit a rapid turnover rate. Theoretically,

hog cycles occur every four years as well as annually. The four year cycle is based on one year time lags between price, pig crop, and slaughter [11]. Without the influence of exogenous variables such as the price and supply of feed grains and price support programs, the cycle has a definite pattern over a four year period. Harlow developed Figure 1 which has a two year response period between price and marketing based on the assumption that year one's price determines the size of year two's pig crop, which in turn resolves year three's slaughterings. In the two year response period, twelve months are accounted for from the time of breeding to slaughter. The other year is accounted for by the time lag between one year's price and the following year's breeding; however, this period is not always twelve months. Harlow used the cobweb theorem based on two year response periods to illustrate the four year cycle. When the cobweb theorem is utilized, the exogenous variables can be considered in the diagram. The cobweb diagram reflects the inverse relationship between quantity and price.

Utilizing Harlow's methodology, Figure 2 was developed from Alberta statistics [2]. Production volumes and average prices from 1957 to 1969 for Alberta Grade A (1969 index = 100) were used. A two year time lag between prices and volumes was used to illustrate the two year response period mentioned previously. If the price started high in 1957, the price should be down in 1959 due to an increase in the volume of hogs marketed as a result of the high 1957 price. In 1961, the price should be back up because of the decrease in volume caused by the low price in 1959. Illustrated in the graph is the four year cycle completed from 1957 to 1969. In 1963, the volumes of marketings did not increase as would be expected because of the price increase in 1961. Such discrepancies

Figure 1

HYPOTHETICAL RELATIONSHIPS BETWEEN MEASURES OF THE HOG CYCLE

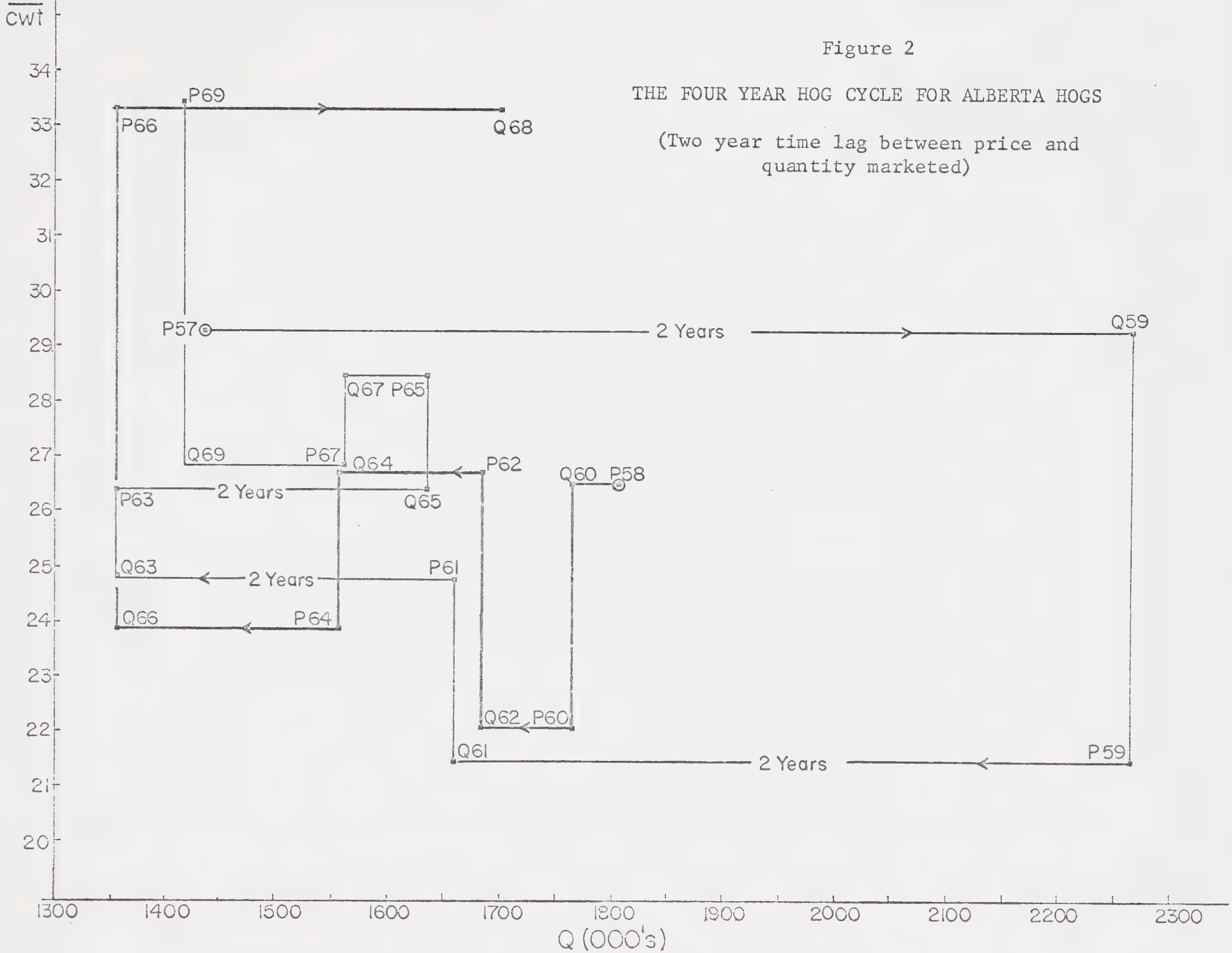


Source: A.A. Harlow, "The Hog Cycle and the Cobweb Theorem" (Journal of Farm Economics, Volume 42, 1960), p. 844.

Figure 2

THE FOUR YEAR HOG CYCLE FOR ALBERTA HOGS

(Two year time lag between price and quantity marketed)



in the hog cycle are caused by the many exogenous variables affecting hog production. The results from the use of the cobweb theorem would suggest that too much emphasis can be placed on price as a supply determinant.

The annual or seasonal cycle causes supply fluctuations every year. This cycle occurs because of the producer's tendency to plan farrowings for the spring and fall months, which usually results in heavy marketings around March and April, and November and December.

The uncertainty created by the hog cycle is an inconvenience to everyone involved in the market channel. There is a possibility that through improved marketing efficiency the demand and supply of hogs could be coordinated more effectively. Standardization of marketing costs and marketing procedures is one alternative for reducing uncertainty in the market channel. In many instances, assembly and handling charges can be reduced, and marketing charges can be made to correspond more directly to marketing costs [16]. Other alternatives might include increased promotion, more quality control, intensification of market research, and provision for more useful market information and market forecasts to producers. Weekly shipments from assembly points to packing centres could be coordinated to provide a uniform flow of hogs. The removal of excess capacity in the assembly and packing operations could result in considerable cost savings. The degree to which producers would benefit depends largely on how they change their output as a result of higher profits. However, as productive units become more specialized and capital intensive, the yearly supply of hogs will become more consistent. Specialized units are forced into a yearly operation in an effort to spread their fixed costs over more units of production. The

importance of the hog cycle can be expected to decline as a result of production specialization and increased marketing efficiency.

Size of Production Units

There has been a definite trend toward specialization and larger productive units in the swine industry. This trend is evident in the 1966 census for Alberta with 45,643 farmers reporting hogs in 1956, 40,017 in 1961, and 28,544 in 1966. However, the small producer is still important; 50 percent of our hogs come from farms marketing less than 62 pigs per year [18].

In 1967, producers' net returns to labor and management varied (according to size and efficiency of producers) from $2.76 to $10.62 per hog for farrow to finish enterprises and from -$2.32 to $5.20 per hog for feeding enterprises* [1]. Such narrow profit margins require productive units to be either large full-time operations or smaller operations that are supplementary and/or complementary to the farm unit. Hog production can be supplementary by employing unused labor (e.g., children) and complementary by providing an outlet for feed grains. Regardless of the size of a commercial hog operation, the manager must recognize the importance of feed and labor efficiency since these two factors represent approximately 75 percent of the production costs. Another 10 percent involves utilities, veterinary fees, and other variable costs. The remaining 15 percent is considered fixed costs [1].

Location of Production Units

Approximately 75 percent of the swine industry in Alberta is located in the central area indicated in Figure 3. Hog production is concentrated

*Return to labor and management is equal to the gross return per hog, minus variable costs, depreciation, insurance, and interest incurred in producing the hog.

in this area because of the cultural background of the residents, the abundance of feed grains, and the proximity to highways and markets. Hogs provide one of the primary outlets for feed grains in this district.

Marketing Organization

> Marketing is (1) performing all business activities required in getting products to consumers in the volume, form or quality, place, and time desired and (2) providing an intricate system of pricing and communication [20].

Marketing efficiency or performance is a function of operational efficiency (number 1 above) and pricing efficiency (number 2 above). Operational efficiency is dependent upon (1) functional organization and (2) spatial organization in the market. Functional organization involves the various services performed by agencies in the market channel, such as, assembly, transportation, processing, and distribution.* Spatial organization involves the origins and destinations of the product and the location of the facilities used to perform the assembly and distribution functions. The objective of operational efficiency is to minimize the marketing costs for each unit of product.

Pricing efficiency concerns the accuracy, speed, and effectiveness with which marketing information is developed and disseminated, as well as the costs associated with such a function [21]. Pricing efficiency is dependent upon the nature of competition and the balance of economic power in the market [14].

The objectives for improving pricing efficiency are to forward benefits from improved operational efficiency on to producers and

*Kohls classifies the market functions as (1) Exchange functions: buying and selling; (2) Physical functions: storage, transportation, and processing; and (3) Facilitating functions: standardization, financing, risk-bearing, and market intelligence.

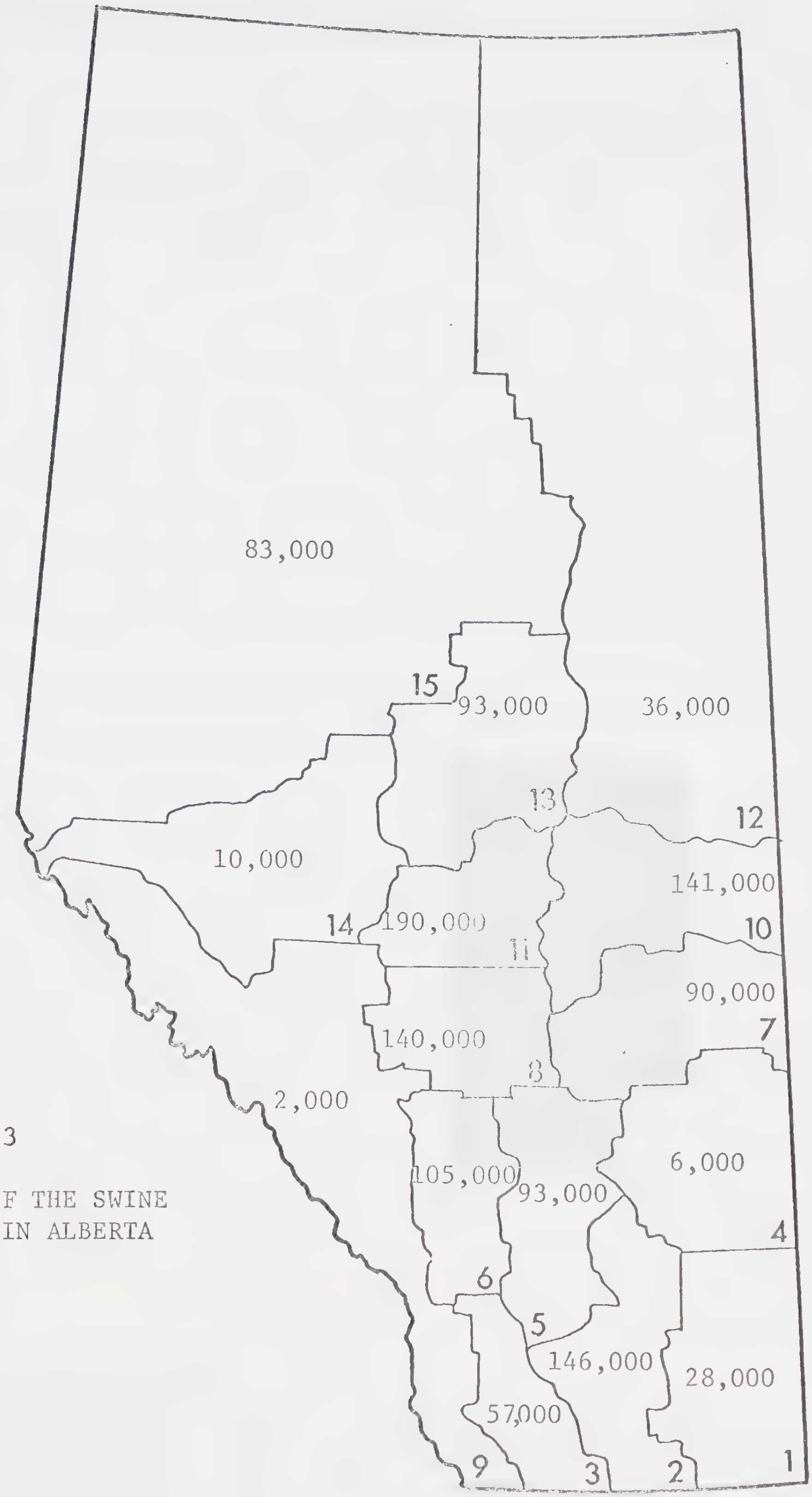


Figure 3

LOCATION OF THE SWINE INDUSTRY IN ALBERTA

Source: Alberta Department of Agriculture (Preliminary Swine Population Estimate, June 1970).

consumers and to improve the operation of the buying, selling, and pricing aspects of marketing [21]. The correlation between operational and exchange efficiencies determines their effects on overall market efficiency. An improvement in one does not always result in an improvement in the other or in overall market efficiency. Firms that are large, relative to the industry as a whole, are generally considered operationally efficient; small firms, relative to the whole industry, are generally considered to be exchange efficient. The ideal is to find the optimum combination of operational and exchange efficiency.

Bain's performance goals apply well to the marketing process of the hog industry [4]. These goals are:

(1) Technical efficiency in scale and rate of utilization of plants and firms within the industry.

(2) Absence both of chronic monopolistic excess profits and of chronic net losses [implying allocative efficiency and equitable income distribution].

(3) "Adequate" progressiveness in the development and innovation of improved or new techniques and products.

(4) Absence of excessive selling costs.

(5) Desirable level and variety of product qualities and designs.

Although the factors mentioned by Bain are difficult to measure quantitatively, they represent the performance goals for an efficient marketing system.

Functional Organization

In this study the four major functions to be considered in the hog market channel are: (1) assembly, (2) exchange, (3) processing, and (4) distribution. Since The Board originated, many changes have been made in selling and pricing techniques and in the procurement practices of the packing houses. The flow of Alberta slaughter hogs for 1968 is

summarized in Figure 4. Movement of hogs since The Board began operation has changed very little. Terminal yards currently function as assembly centres and do no selling. Direct deliveries will be reduced as a result of the lot size requirement set by The Board. To date, figures are not available for a full year's operation of The Board; however, Figure 5 depicts the present market channel. A description of the functional organization and changes brought about by The Board follows.

Assembly--The purpose of assembly has always been to form lots large enough for economical transport and sale. The majority of the individuals and organizations involved in assembly provide such additional services as tattooing and transportation to the market. Assemblers are known as (1) shippers, (2) trucker-assemblers, (3) shipping associations, or (4) commission firms. Some of the large producers can bypass the assembly function and deliver direct to the purchaser following sale by The Board. The minimum lot size handled by The Board is twenty hogs (Table 5).

Shippers provide facilities for the assembly of hogs. Before The Board became effective, many shippers were affiliated directly with a particular packing plant or operated buying stations owned by a processor. Since all hogs are now sold through The Board, there are few agreements between shippers and packing plants. Companies that had owned buying stations have discontinued assembling hogs and have either sold or leased their facilities to independent operators.

The second type of assembler is the trucker-assembler. Most of these assemblers operate an assembly yard to complement their trucking business. In some instances truckers assemble their loads by traveling from farm to farm in their territory and do not require assembly facilities.

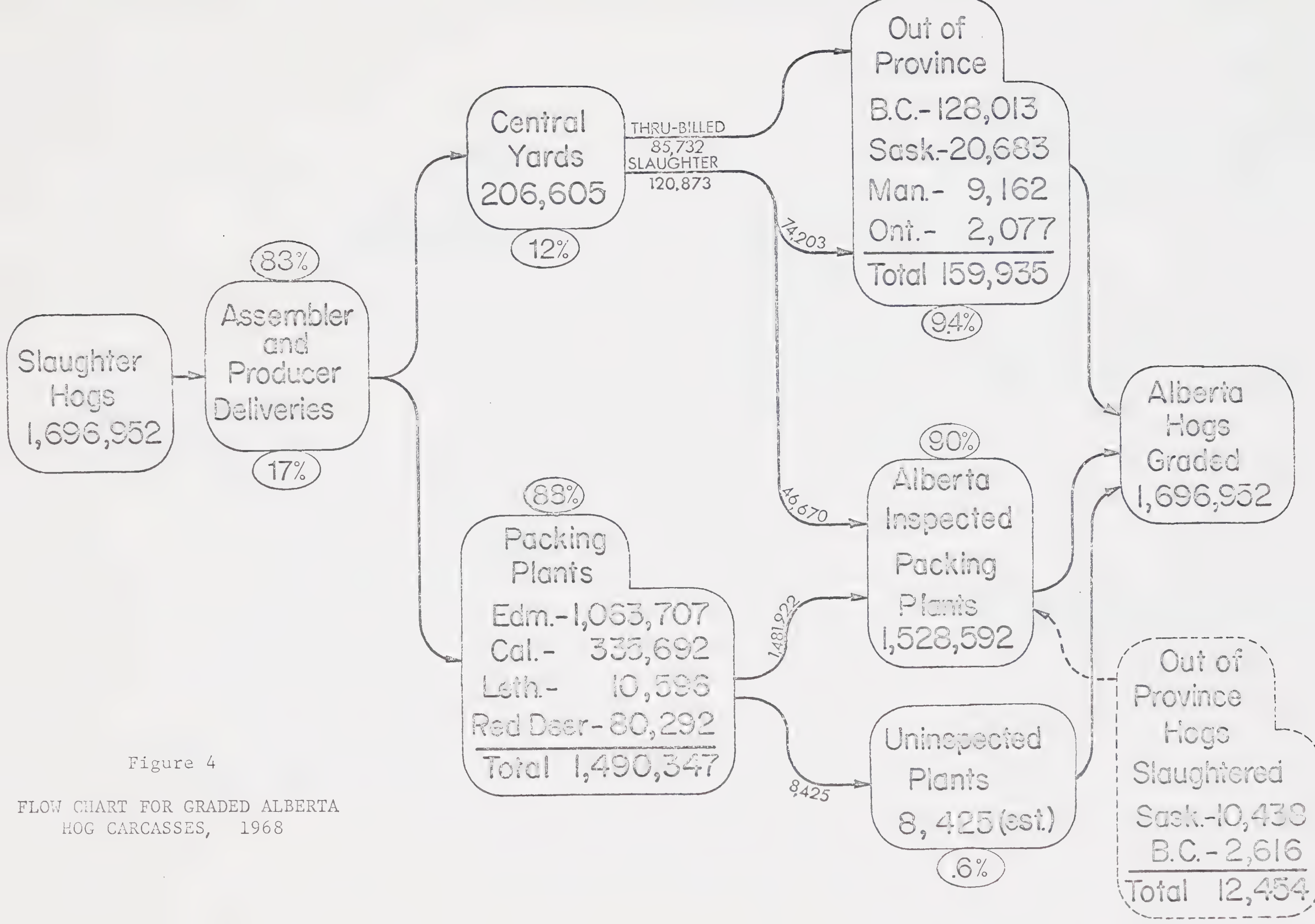
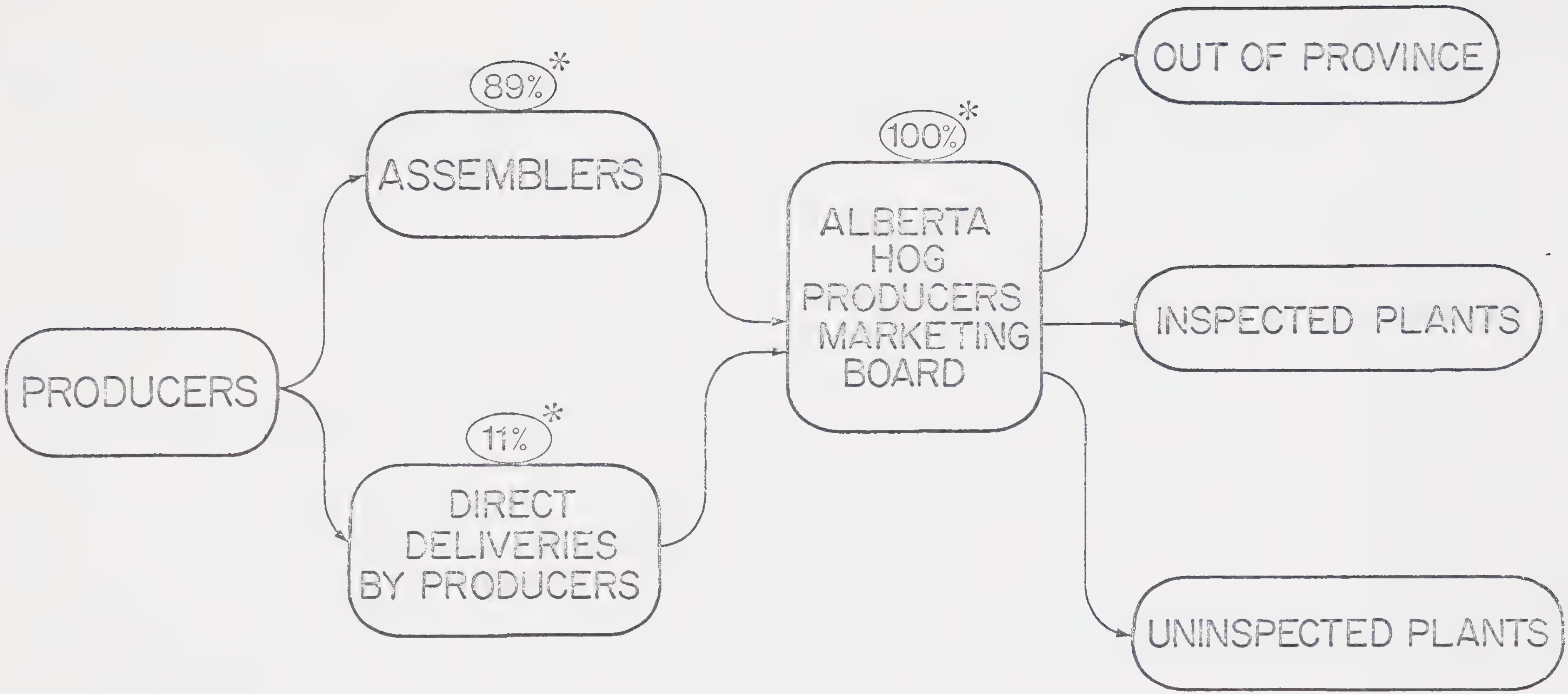


Figure 4

FLOW CHART FOR GRADED ALBERTA HOG CARCASSES, 1968



*Percentages are based on one month's marketings by the Board.

Figure 5

FLOW CHART FOR HOGS MARKETED, 1970

Table 5

PERCENTAGE OF HOGS HANDLED BY DIFFERENT AGENCIES IN ALBERTA (1965)		ESTIMATED PERCENTAGE OF HOGS HANDLED BY DIFFERENT AGENCIES IN ALBERTA (1970)	
Private shippers and truckers	45.9%	Shippers	19.0%
Buying stations	14.9%	Trucker-Assemblers	35.0%
ALC	18.0%	ALC and small cooperatives	25.0%
Commission firms (terminal markets)	2.5%	Commission firms	10.0%
Direct to plants	18.7%	Producers direct to purchaser	11.0%
Total	100.0%	Total	100.0%

Source: W.J. Lockhart, "Alberta Hog Market, Conduct and Performance" (unpublished MSc. thesis, University of Alberta, Department of Agricultural Economics, 1967), p. 38.

Source: Alberta Hog Producers Marketing Board. (Based upon the volume sold for April 1970.)

The services provided by shipping associations are similar to those of shippers. These associations, of which the Alberta Livestock Cooperative is the largest, are operated as producers' cooperatives. They assemble and offer lots for sale through The Board. In the past, the majority of the shipping associations cooperated with the ALC and handled up to 19 percent of the hogs marketed in Alberta [15]. The large volume gave the ALC a relatively strong position for price negotiating with the meat packers. The ALC continues to act as an order buyer for some packing plants in British Columbia; however, it has lost some of its price influence as a result of the new selling system.

Prior to the inception of The Board, commission firms located at terminal markets assembled hogs delivered by the truckers and farmers. In Calgary commission firms offered some hogs for sale through public auction, while in Edmonton most hogs handled by commission firms were sold to out-of-province buyers at the established auction price.

The role of commission firms remains much the same with the exception that all hogs are sold by The Board and none are offered for sale at central markets. These firms continue to act as buyers for out-of-province processors.

The last consideration for the movement of slaughter hogs from the farm is that of direct shipments by the producer. A direct shipment bypasses all of the previously mentioned assemblers and goes directly to the purchaser after the sale is made by The Board. The number of direct deliveries is restricted by the minimum lot size and also by the distance a producer has to travel to the market.

In 1968, Alberta had over 300 hog assembly locations with more than 500 assemblers [19]. Volumes handled by individual assemblers are not

available; however, data has been tabulated for each assembly location. Table 6 shows the relative volumes of hogs handled in 1968 for the different locations. Taking all the locations into account, there were 114 that assembled less than 500 hogs and only 67 that assembled more than 5,000 hogs. With more than one assembler at some of these locations, it can be concluded that little specialization exists in the assembly process. Of the 1,696,952 Alberta hogs graded in 1968, approximately 83 percent or 1,412,400 were handled by assemblers. The remaining 17 percent or 284,552 were delivered direct to terminal markets or to packing plants by producers. Direct estimates will be low because some direct shipments from large producers were included in assembly figures. All shipments by assemblers were either to terminal markets or to packing plants; however, information as to which location individuals delivered their hogs is not available. The available information is summarized in Table 7.

Exchange--The second major function in the market channel is that of exchange. All selling and buying is done through The Board's teletype system on a descending Dutch-auction basis. Hogs are offered for sale in lots of 20 or more, and the asking price is conveyed simultaneously to all buyers. The asking price is calculated from pre-punched descending scale tapes that drop the price in gradations of five cents. Information given on the tape includes the date, the F.O.B. point or points, the estimated time of delivery, and occasionally the producer's name. The producer can choose one or more F.O.B. delivery points. These points are Grande Prairie, Lloydminster, Lethbridge, Red Deer, Calgary, and Edmonton. Any producer marketing a lot of 20 or more hogs can sell directly through The Board and have his name on the shipment; smaller

Table 6

DISTRIBUTION OF ASSEMBLY TOWNS ACCORDING TO VOLUMES HANDLED, 1968

Census Division	< 500	500 to 1000	1000 to 2000	2000 to 3000	3000 to 4000	4000 to 5000	5000 to 7500	7500 to 10000	10000 to 12500	12500 to 15000	15000 to 17500	17500 to 20000	20000 to 25000	25000 to 30000	30000 to 40000	40000 to 50000	50000 +	Total
1	3				1		1											5
2	9	1	2	2		1	1	2	1								1	20
3	4	2	1	2		1			1									11
4	6		1															7
5	12	2			2	1		1	1									19
6	3	2			1		2	1									1	10
7	4	1	7	7	3	3	1	1				1						28
8	3		3	4	5		2	2		1		1		1	1		1	24
9	2			1														3
10	11	5	8	4	1	2	5	4	2			1	1			1		45
11	17		3		1		2	1	2	1	1			1	2			31
12	4	1	5	2	1	1	3	1	2			1						21
13	21	1	7	4	1	1	4	1	1	1					2			44
14	3			1														4
15	12	1	8	2	3	6	1					1						34
Total	114	16	45	29	19	16	22	14	10	3	1	5	1	2	5	1	3	306

Source: Tabulated from Swine Industry Data Bank (1967-1968), Department of Agricultural Economics, University of Alberta.

Table 7

DELIVERIES AND DESTINATIONS OF ALBERTA SLAUGHTER HOGS, 1968

Type of Delivery	Numbers Delivered	Percentage	Destination	Numbers Received	Percent
Direct by Producers	284,662	17	Packers	1,490,347	88
Assembler Deliveries	1,412,400	83	Terminal Yards	206,605	12
Total	1,696,952	100		1,696,952	100

Source: Data tabulated from Swine Data Bank (1967-1968), Department of Agricultural Economics, University of Alberta.

producers sell under their assembler's name. In the past, hog producers were paid either by the packers or by the assembler. Now The Board controls all payments.

Prior to the formation of The Board, approximately 5 percent of all hogs were sold by public auction at terminal markets [17]. Most hogs were purchased through private shippers, buying stations, and the ALC. Producers were dissatisfied with the pricing and bargaining procedures utilized. Details of the old and new selling systems follow in the section on exchange efficiency.

Processing--The third function in the market channel for hogs is processing. In Alberta, the packing houses are centred in Edmonton, Calgary, and Red Deer. Major companies operate four plants in Edmonton and two in Calgary. There are two smaller packing plants that slaughter hogs in Red Deer, two in Edmonton, and one in Lethbridge. All major packing plants are government inspected; however, it is estimated that 20 percent of the market hogs in Canada are slaughtered at uninspected establishments [18]. This percentage would be much the same for Alberta.

Packing plants play a vital role in the marketing of pork. Since most packers provide retailers with a ready-to-sell product, they share much of the responsibility of providing a product suitable to consumer tastes. An effective merchandising program is required to sell the final product. Such a program involves the development of new products; coordination between processing, retailing, and consumer demands; packaging; and product promotion. The operational and marketing efficiency of meat packers is complicated by the uncertain supply of hogs caused by production cycles.

Distribution--The final activity in the functional organization is

distribution, which involves wholesaling and retailing. The amount of meat handled by wholesalers has been declining as corporate chain sales have increased. Meat is sold by processors directly to the chain store buyers, to wholesalers representing voluntary chains, and to wholesalers specializing in commercial cuts and additional processing. There are few independent wholesalers that handle meats because of the perishability of the product.

The food retailer is the final link between the product and the consumer. Retailers have considerable freedom to adjust pricing and selling strategies and, therefore, hold much of the responsibility for selling pork and other products. The influence of the retailer's strategy depends upon the cross elasticities of substitute goods such as poultry and beef.

Spatial Organization

Alberta has a favorable location in the North American market for pork. The main deficit areas are in Eastern Canada, British Columbia, and the western United States. The United States provides an outlet for live hogs as well as for quality cuts. In 1968, the western provinces produced 35.1 percent of the Canadian hog gradings while the east produced 61.9 percent [5]. However, the western provinces accommodated only 26.6 percent of the Canadian people, while the eastern provinces served 73.4 percent of the population. In 1968, Alberta marketed nearly 55 percent of the western gradings and 20.8 percent of the federal gradings (Table 8).

Hogs are marketed from every census division except number 9. Census divisions 8, 10, 11, and 13 delivered over 60 percent of the hogs that were government graded in 1968. Divisions 2, 6, 7, and 12 accounted

Table 8

CANADIAN POPULATION BY PROVINCE AND PERCENT OF HOG GRADINGS, 1968

Province		-000- Population	% total	% of hog gradings	# of gradings
N.W.T.		31	0.2	-	
Yukon		15	-	-	
B.C.		2,010	9.7	0.7	59,718
Alta.		1,529	7.4	20.8	1,696,952
Sask.		961	4.6	7.4	600,986
Man.		972	4.7	9.2	746,373
	West	(5,518)	(26.6)	(38.1)	(5,041,118)
Ont.		7,321	35.2	34.8	2,830,724
Que.		5,930	28.6	23.3	1,895,925
N.B.		625	3.0)		
N.S.		760	3.7)		
P.E.I.		110	0.5)	3.8)	314,469
Nfld.		508	2.4)		
	East	(15,254)	(73.4)	(61.9)	(5,041,118)
Canada		20,772	100.0	100.0	8,145,147

Source: R.K. Bennett, "The Position of the Canadian Hog Producer Operating on the North American Economy" (Paper prepared for the Canadian Agriculture Congress, Ottawa, March 1969).

for 27 percent, as shown in Table 9.

Prior to the formation of The Board, hogs received at public stockyards were sold to buyers either through public auction or by direct negotiation with commission firms or the ALC. The hogs received were either sold for slaughter or sold as feeders. "Thru-billed" hogs were not offered for sale at the yards, but provisions were made for stop-off points enroute to the purchaser. Disposition of hogs from Alberta stockyards is shown in Table 10.

Alberta's pork exports are destined primarily for markets in British Columbia, Eastern Canada, and Western United States. Specific figures relating volumes and their destinations are not available. In 1968, 1,537,017 hogs were slaughtered and graded in Alberta. Utilizing an average carcass weight of 150 pounds, it can be assumed that about 148,600,000 pounds of pork were available for shipment, providing consumption in Alberta conformed to the national average. If this estimate is reliable, 35 percent of Alberta's pork is consumed in Alberta.

Pricing and Exchange Efficiency

In the past, hogs sold by public auction at terminal markets have been credited with establishing the "base" price for all hogs sold in Alberta. In 1968, 2.8 percent (or 46,670) of the hogs marketed were sold to Alberta packers by terminal markets, and the majority of these were not sold by auction. Of the 206,605 hogs handled by terminal yards, 77 percent were purchased by out-of-province buyers and 23 percent by Alberta packers. There were other price determinants besides terminal markets since over 97.2 percent of the hogs purchased for slaughter in Alberta were not sold by public auction. The final price for these hogs was determined by limited negotiation between sellers and buyers.

Table 9

SUMMARY OF ALBERTA HOG CARCASSES GRADED BY CENSUS DIVISION, 1968

Census Division	Total
1	12,644
2	123,293
3	37,416
4	5,751
5	70,821
6	131,499
7	98,408
8	251,473
9	-
10	260,151
11	306,893
12	106,033
13	204,982
14	4,100
15	83,488
1968	1,696,952

Source: Canada Department of Agriculture, Forty-Ninth Annual Livestock Market Review (Ottawa: CDA, 1968).

Table 10

DISPOSITION OF HOGS FROM ALBERTA PUBLIC STOCKYARDS, 1968

Centre	Slaughtered	Thru-Billed	Feeders	Total
Lethbridge	47,427	13,888	21,269	82,584
Calgary	35,942	56,776	3,468	96,186
Edmonton	37,504	15,068	51,732	104,304
Total	120,873	85,732	76,469	283,074

Source: Canada Department of Agriculture, "Annual Livestock Market Reports (Edmonton, Calgary, Lethbridge)" (Ottawa: CDA, 1968).

The term "limited negotiation" is used because with about 28,000 producers and relatively few buyers we have an oligopsonistic market situation.

Alberta hog prices are influenced by price levels in both the Canadian and North American markets. In the Canadian market, Alberta hog prices are affected by the Toronto-Montreal price. In past years the Alberta price has been three to four dollars per hundredweight below the eastern price or five to six dollars less per hog. The difference in price purportedly is explained by the freight differential to the East, although the largest percentage of Alberta's pork is shipped west.

Canada's share of the North American pork production is 8.7 percent; therefore, some relationship can be expected to exist between the Canadian and United States hog prices. Toronto price levels are dependent to some extent on those of the larger United States markets; however, because there are continuous inward and outward flows of pork between the United States and Canada, the degree of price influence is difficult to measure. R.K. Bennett, director of the Livestock Division of the Canada Department of Agriculture, states that the United States price level at all times provides a "price ceiling" and a "price floor" for the Canadian hog market [5]. Such a relationship exists because of the free movement of pork between the two countries. During the years of 1966, 1967, and 1968, Canada's average weighted price* was $3.95 per cwt or about $5.90 per carcass higher than the United States price. Given the relatively free movement of pork in North America, perhaps the first potential location for improvement of pricing and exchange efficiency should be the local

*Average weighted price refers to "National Average Weighted Price" which includes the price paid for all hogs except indexes 67 and 80, and sows and stags, plus transportation charges, commission insurance, and other directly related expenses or charges paid [5].

or domestic market.

One accomplishment of The Board has been the improvement of exchange efficiency in the Alberta market. This has been achieved by replacing the former pricing mechanism offered by terminal markets and packers. In place of the "base" price system and negotiation between sellers and buyers, The Board controls all sales. Discrepancies such as trucker bonuses and collusion between buyers have been reduced in the market. With The Board as the single selling agency, all buyers have equal opportunity to bid on all hogs offered for sale. While benefits to producers may not be in the form of higher prices, total returns may increase by using daily market information which is readily available to all producers. Such information should facilitate a more uniform flow of hogs through the market to the benefit of all participants in the market channel.

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CHAPTER III

A SPATIAL MODEL

Theoretical Background and Model Statement

> In location theory economic analysis is used to study the geography of man's economic activities and also to study the effects of space on the organization of economic activities. Historically, it has developed from a study of the location of plants and of an industry to a more inclusive analysis of the spatial pattern of all economic activities [1].

Theoreticians in the past have been concerned primarily with the time dimension of economics and have underemphasized spatial effects, even though all economic processes exist in space. Economic justifications for spatial differentiation include economies of scale, transport cost, the need for raw materials and markets, and the need for space itself. Transportation can be considered as a production input, along with such other factors as land, labor, and capital.

German economists were among the first to attempt fusing spatial economics with general equilibrium analysis. Von Thünen developed a location theory based on a series of concentric zones around a market centre [5]. These zones defined the types of agricultural products to be produced according to transportation costs and the perishability of the produce. Von Thünen's analysis involved the spatial location of the agriculture industry as a whole and did not consider the location of the individual firm.

Weber's theory centred on the location of individual firms. He emphasized three primary locational forces: transport cost differentials, labor cost differentials, and agglomeration (deglomeration) economies

and diseconomies [3]. Agglomeration (deglomeration) factors include economies of scale within a firm, localization economies for all firms in a single industry, and urbanization economies [4].

Lösch [8] pictured spatial differentiation as a network of hexagons created by the competitive forces among firms. The hexagon shape minimizes transport costs for each market area. Size of the hexagon is dependent upon the demand for the product and upon freight rates for the raw materials and the finished product. Ideally, people would be expected to live where their average distance from all required facilities is minimized.

Beckman [1] notes that space enters economic relationships in two ways: (1) through transportation costs and (2) through neighborhood effects. The neighborhood effects are similar to Weber's agglomeration effects except that they include social costs to individuals as well as to firms and industries. Compared to transportation costs, these "social costs" are difficult to measure and are often overlooked in spatial problems. However, because the social costs may outweigh the benefits created by the minimization of transportation costs, both should be considered.

The long-run spatial model (LRSM) used in this study resembles, but extends, the linear programming transportation model. The linear programming model is designed to minimize transportation costs between a fixed number of supply and demand nodes; it is concerned only with minimizing costs for the aggregate. Normally no consideration is given to the economies of each individual firm. The linear programming model is generally applicable for analyzing short-run situations where supply and demand nodes must remain fixed. The LRSM allows the number,

size, and location of businesses to vary so that costs may be minimized for the aggregate and also for the individual firm. Such a model is used primarily for long-run planning and decision making. The general spatial model was developed by Stollsteimer [7] in 1961, and in 1967 Warrack [9] devised techniques that would allow the model to be utilized in large-scale problems.

The basic problem in this study is to determine the optimum number, location, and size of hog assembly stations in Alberta that will minimize the combined assembly and transport costs from producers to packing centres. It is assumed that assembly costs for equal-volume facilities should not vary from one locality to the next nor should transportation rates vary for locations at equal distances from the market. The assumptions are made on the basis that operational costs for assembly centres are not influenced by distance from markets and transportation rates are dependent upon mileage. The prime factor affecting assembly costs is the volume handled, indicating economies of size.

The total combined cost function to be minimized may be stated as follows:

$$TCC = TAOC + TFATC + TASTC \tag{1}$$

with respect to the number of assembly locations,

where TCC = total combined cost

TAOC = total assembler operating cost

TFATC = total farm (production reference point) to assembly transportation cost

TASTC = total assembler to slaughter centre transportation cost.

Algebraically, the model is :

$$\underset{(J,L_k)}{\text{MIN TCC}} = \sum_{j=1}^{J} P_j \, H_j \Big|_{L_J} + \sum_{f=1}^{F} \sum_{j=1}^{J} H_{fj} \, T_{fj} \Big|_{L_J} + \qquad (2)$$

$$\sum_{j=1}^{J} \sum_{j=1}^{I} H_{ji} \, T_{ji} \Big|_{L_J}$$

with respect to the number of assembly locations ($J \leq L$) and locational patterns $L_J = 1,2,\ldots\ {}_L C_J$, are subject to:

$$\sum_{j=1}^{J} \sum_{j=1}^{I} H_{ji} = \sum_{f=1}^{F} \sum_{j=1}^{J} H_{fj} = H$$

$$\sum_{j=1}^{J} H_{fj} = H_f \qquad \sum_{f=1}^{F} H_{fj} = H_j$$

$$\sum_{i=1}^{I} H_{ji} = H_j \qquad \sum_{j=1}^{J} H_{ji} = H_i$$

$H_{fj} \geq 0$, $H_{ji} \geq 0$, $T_{fj} \geq 0$, $T_{ji} \geq 0$, $P_j \geq 0$

where $i=1,2,\ldots I$; $j=1,2,\ldots J$; and $f=1,2,\ldots F$.

In the above,

TCC = total combined cost composed of assembly operational costs, transportation costs from production reference points* to assembly locations, and transportation costs from assembly locations to packing centres

H = quantity of hogs demanded

H_f = quantity of hogs supplied at production reference point f

H_j = quantity of hogs assembled at assembly location j

*Production reference points refer to the central location chosen for each census subdivision to represent the centre of production. These points are in the same locations as the potential assembly sites.

H_i = quantity of hogs demanded at packing centre i

H_{fj} = quantity of hogs shipped from production reference point f to assembly location j

H_{ji} = quantity of hogs shipped from assembly location j to packing centre i

T_{fj} = transportation cost from production reference point f to assembly location j

T_{ji} = transportation cost from assembly location j to packing centre i

P_j = assembly cost per hog at assembly location j

L_k = one combination of locations for J assembly centres among the ${}_LC_J$ possible combinations of locations for J assembly centres, given L potential locations

L_j = location of assembly centre j

L_J = all possible combinations of locations for J assembly centres.

Solution Procedure

The first step in the solution procedure is to minimize the transportation cost function for producers to assemblers, with respect to the number of assembly locations.

Minimize:

$$\sum_{f=1}^{F} \sum_{j=1}^{J} H_{fj} \, T_{fj} \mid L_J \tag{3}$$

For J assembly locations there are ${}_LC_J$ possible combinations of $L_k \mid J$. For example, if the location of three assembly centres is being considered for five possible locations, there will be $\frac{5!}{3! \; 2!} = 10$ different ways to locate them; in other words, there are ten possible $L_k \mid J$ combinations for the three assembly locations. For each combination $L_k \mid J$ there is a submatrix $C_{fj}* \mid L_k$ taken from a large matrix (C) that displays transportation costs from every production reference point to all the potential assembly

locations. The dimensions of the cost sub-matrix will be (F by j) where F represents the production reference points and j represents the number of assembly locations being considered. The entries in each column represent the transport costs from every supply location to one assembly location. The sub-matrix $C_{fj}{}^{*}|L_k$ is scanned by rows and the minimum cost (C_{fj}) for each row is selected. These minimum transfer costs form a vector $C_{fj}|L_k$ with dimensions (60 by 1). To derive the total transport cost, the vector $C_{fj}|L_k$ is multiplied by the volumes supplied at each production reference point,

$$C_{fj}|L_k\ (H_f{}^{\circ}),$$

where $H_f{}^{\circ}$ represents a vector of quantities marketed from each production reference point. For each value of j, there are ${}_{L}C_{J}$ total transport values. The minimum of all these combinations (L_k's) forms a minimum point on the transportation cost function. There are j of these minimum points:

$$TFATC^{min} = \underset{L_k}{\min}\ [C_{fj}|L_k(H_f{}^{\circ})], \tag{4}$$

where transportation cost from producers to assemblers (TFATC) is minimized with respect to assembly locations for each j = 1, 2, ... J.

The general shape of the minimum TFATC function (Figure 6A) can be demonstrated using the first and second differences with respect to assembly location numbers [6]. Since transportation costs decrease with additional assembly locations, the first difference of the minimum TFATC cost function with respect to location numbers can be expected to be zero or negative:

$$\frac{\Delta\ TFATC^{min}}{\Delta\ J} \leq 0. \tag{5}$$

The above inequality is true so long as there is a sub-matrix of C_{fj} (called $C_{fj}{}^{**}$) representing assembly locations not being considered

(i.e., considering only j assembly locations), such that $C_{fj}^{**} < C_{fj}^{\min}$ for j locations.

The second difference of the TFATC $^{\min}$ function will be either positive or zero as the number of assembly locations increases:

$$\frac{\Delta^2 \text{ TFATC}^{\min}}{\Delta J^2} \geq 0. \tag{6}$$

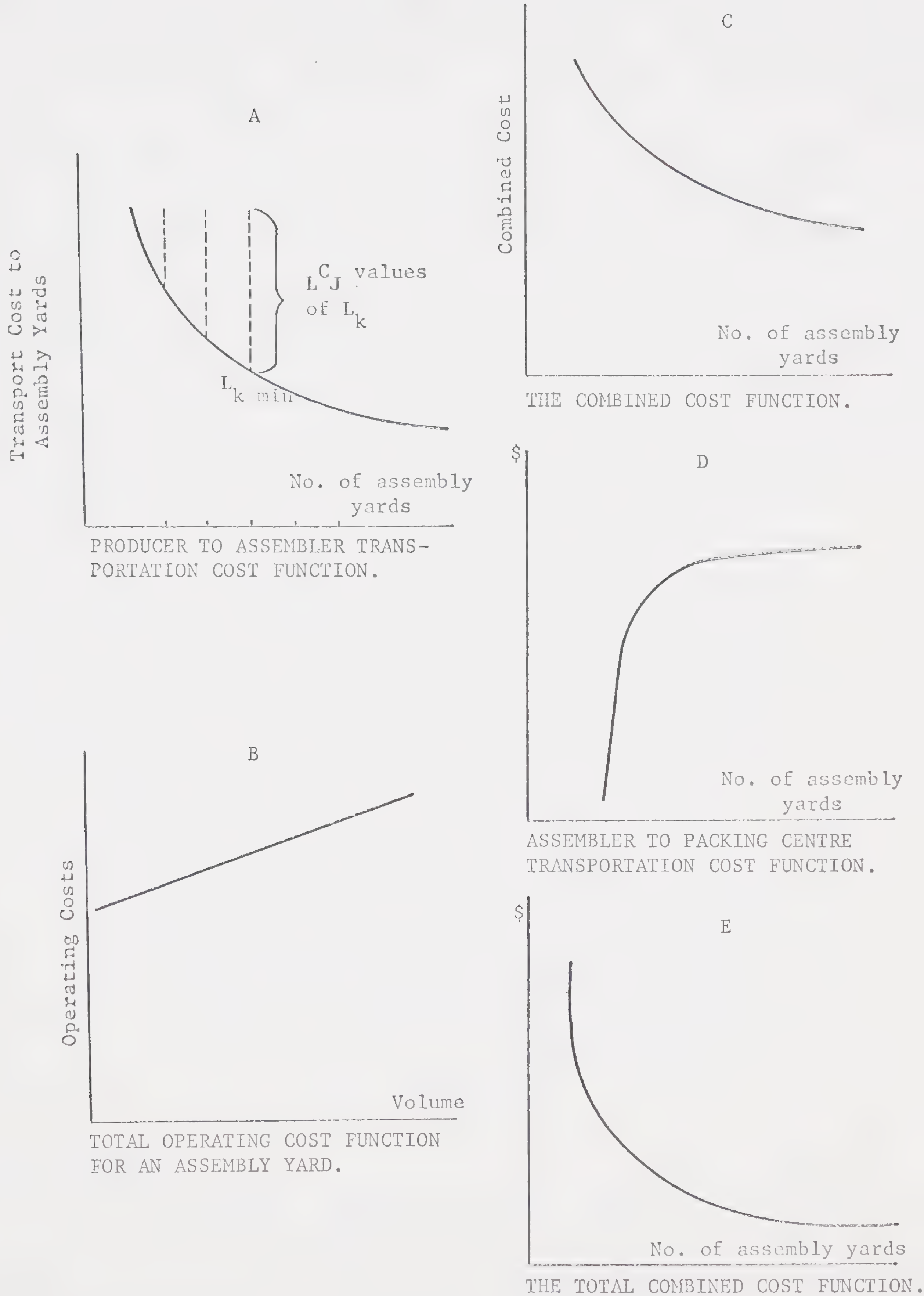
Use of second differences is not always as conclusive as is use of first differences for proving the convexity of a function, since it is possible for a second difference to be negative if more than one vector is being considered [11]. However, in this study only one vector is considered.

With the number of assembly locations (j) established to minimize producer to assembler transport costs, the total assembly operational costs (TAOC) can be obtained. For an individual assembly location the total operating cost function (Figure 6B) has a positive intercept indicating fixed costs and the function slopes upward as TAOC increases with additional volume. Each additional assembly location can be expected to raise the total operational cost by any change in the variable cost for each hog assembled plus the amount of the intercept. It has been shown that the TFATC decreases with additional assembly locations while the TAOC increases. For the combined cost function to decrease, the effects of lowering the TFATC must be greater than the increase in TAOC as more assembly locations are utilized.

The locational pattern and volume for each number of assembly locations is established in the TFATC minimization procedure. With this volume information the TAOC can be calculated for each number of assembly locations (j) through the summation of each assembly operational cost in J. The combined cost function is computed by the vertical summation

Figure 6

COST FUNCTIONS



of the minimum TFATC and TAOC for each number of assembly locations.

$$\underset{(J)}{CC} = \underset{(J)}{TFATC^{min}} + \underset{(J)}{TAOC} \qquad (7)$$

Figure 6C illustrates the combined cost function for assembly locations.

The final step in the solution procedure is to derive the transportation costs from the assembly locations to the nearest plant for each L_k solution. As the number of assembly locations increases, the transportation cost from assemblers to packers (TASTC) should increase because this is a decentralizing condition (Figure 6D). These transportation costs can be calculated through use of the linear programming transportation model. Volumes have already been established for assembly locations, and the demand at packing centres is fixed. The transportation model distributes the assembly volumes to the nearest packing centres so that transportation costs are minimized. The total combined cost (Figure 6E) is obtained by adding the combined cost for each L_k solution (Figure 6C) to the transportation cost to the plants.

$$\underset{(J)}{TCC} = \underset{(J)}{TAOC} + \underset{(J)}{TFATC}^{min} + \underset{(J)}{TASTC} \qquad (8)$$

Such a solution includes the farm to assembler transportation cost, the assembly operational cost, and the transportation cost from the assembly points to the nearest packing centre. The least-cost solution is at the minimum point on the TCC function that sums the three basic components.

Data Requirements

Supply Analysis

The volumes handled by assemblers for each census subdivision are based upon figures tabulated for 1968 by researchers employed by The Board. The information was compiled directly from each shipping manifest

written by the hog assemblers. Volumes for every census division and census subdivision are indicated in Table 11. In this study it was assumed that 1968 figures would reflect the distribution of future production.

The choice of potential assembly and production reference points* for the subdivisions was based on the following criteria. A subdivision had to ship more than 500 hogs through assembly yards in 1968 to qualify for a potential assembly site.** In most instances only one prospective assembly location was chosen for each subdivision. However, County 1 was allowed two potential sites because of the large area covered; County 23 was allowed two sites because of a very large volume; County 24 was allowed two sites because Lloydminster assembles hogs from Saskatchewan; and Counties 20 and 31 were limited to one potential location between them because their productive areas are small and adjacent to one central location. The determination of a specific town for each subdivision was based on the location and size of the town. It was essential that the town be centrally located in order to minimize the producers' delivery costs. Size of town was also given consideration in an effort to choose locations that are established business centres. In the event of two potential locations fulfilling the above criteria, the town with the largest volume of shipments for 1968 was chosen. Sixty potential assembly sites were selected representing 58 census subdivisions (Figure 7). To illustrate how well Alberta's hog producing

*The potential assembly centres perform a dual role in the analysis. They are assembly centres and also function as production reference points for the area they represent.

**500 hogs was an arbitrary figure chosen for the purpose of eliminating census subdivisions with insignificant shipment volumes. Note: Strathmore was the only exception to this criterion.

Table 11

VOLUME OF HOGS DELIVERED BY ASSEMBLERS FOR EACH
CENSUS DIVISION AND SUBDIVISION, 1968

Census Division	No. of Hogs	Subdivision	No. of Hogs	Potential Assembly Sites
1	9,023	ID. 1	3,991	Medicine Hat
		Cty. 8	5,032	Foremost
2	128,845	MD. 14	15,238	Vauxhall
		Cty. 4	21,512	Brooks
		Cty. 5	2,171	Warner
		Cty. 26	89,924	Lethbridge
3	24,872	MD. 6	6,001	Cardston
		MD. 9	4,944	Pincher Creek
		MD. 26	13,927	Claresholm
4	1,456	SA. 2	1,213	Hanna
		SA. 3	87	
		SA. 4	156	
5	31,357	Cty. 2	933	Vulcan
		Cty. 16	143	Strathmore
		MD. 47	4,889	Drumheller
		MD. 48	25,376	Three Hills
		ID. 7	16	
6	174,235	Cty. 17	22,681	Didsbury
		MD. 31	3,148	High River
		MD. 44	148,406	Calgary
7	85,908	Cty. 6	28,149	Stettler
		Cty. 18	6,975	Castor
		Cty. 29	30,722	Killam
		MD. 52	8,925	Czar
		MD. 61	11,137	Wainwright

Table 11 (Continued)

Census Division	No. of Hogs	Subdivision	No. of Hogs	Potential Assembly Sites
8	250,206	ID. 65	7,264	Eckville
		Cty. 3	31,838	Ponoka
		Cty. 14	65,301	Lacombe
		Cty. 23	145,803 -	Innisfail - 36,475 Red Deer - 109,328
9	143	ID. 8	67	
		ID. 5	76	
10	206,527	Cty. 9	16,063	Holden
		Cty. 21	25,098	Two Hills
		Cty. 22	69,331	Camrose
		Cty. 24	40,388 -	Vermilion - 29,888 Lloydminster - 10,500
		Cty. 27	34,429	Vegreville
		Cty. 30	21,218	Lamont
11	178,046	MD. 90	21,154	Morinville
		Cty. 10	43,320	Wetaskiwin
		Cty. 20 Cty. 31	44,150 52,005	- Edmonton - 96,155
		Cty. 25	17,417	Thorsby
12	89,759	Cty. 13	16,295	Smoky Lake
		Cty. 19	41,117	St. Paul
		MD. 87	26,241	Bonnyville
		ID. 18	6,106	Lac La Biche
13	147,446	Cty. 7	5,681	Thorhild
		Cty. 11	54,937	Barrhead
		Cty. 12	19,201	Athabasca
		Cty. 28	25,362	Sangudo

Table 11 (Continued)

Census Division	No. of Hogs	Subdivision	No. of Hogs	Potential Assembly Sites
13 (Cont'd)		MD. 92	42,004	Westlock
		ID. 107	261	
14	2,891	ID. 14	387	
		ID. 15	2,504	Whitecourt
15	81,624	ID. 16	8,989	Valleyview
		MD. 130	6,707	Falher
		Cty. 1	33,439 -	Beaverlodge - 12,604; Grande Prairie - 20,835
		ID. 17	4,370	High Prairie
		ID. 22	5,919	Manning
		MD. 133	3,185	Spirit River
		MD. 135	5,830	Grimshaw
		MD. 136	4,245	Fairview
		ID. 19	2,255	Eaglesham
		ID. 21	3,169	Hines Creek
		ID. 23	3,516	Lacrete
			1,412,338	

Source: Tabulated from Swine Industry Data Bank (1967-1968), Department of Agricultural Economics, University of Alberta.

1. Medicine Hat
2. Foremost
3. Vauxhall
4. Brooks
5. Warner
6. Lethbridge
7. Cardston
8. Pincher Creek
9. Claresholm
10. Hanna
11. Vulcan
12. Strathmore
13. Drumheller
14. Three Hills
15. Didsbury
16. High River
17. Calgary
18. Stettler
19. Castor
20. Killam
21. Czar
22. Wainwright
23. Eckville
24. Ponoka
25. Lacombe
26. Red Deer
27. Innisfail
28. Holden
29. Two Hills
30. Camrose
31. Vermilion
32. Lloydminster
33. Vegreville
34. Lamont
35. Morinville
36. Wetaskwin
37. Edmonton
38. Thorsby
39. Smoky Lake
40. St. Paul
41. Bonnyville
42. Lac La Biche
43. Thorhild
44. Barrhead
45. Athabasca
46. Sangudo
47. Westlock
48. Whitecourt
49. Valleyview
50. Falher
51. Grande Prairie
52. Beaverlodge
53. High Prairie
54. Manning
55. Spirit River
56. Grimshaw
57. Fairview
58. Eaglesham
59. Hines Creek
60. Lecrete

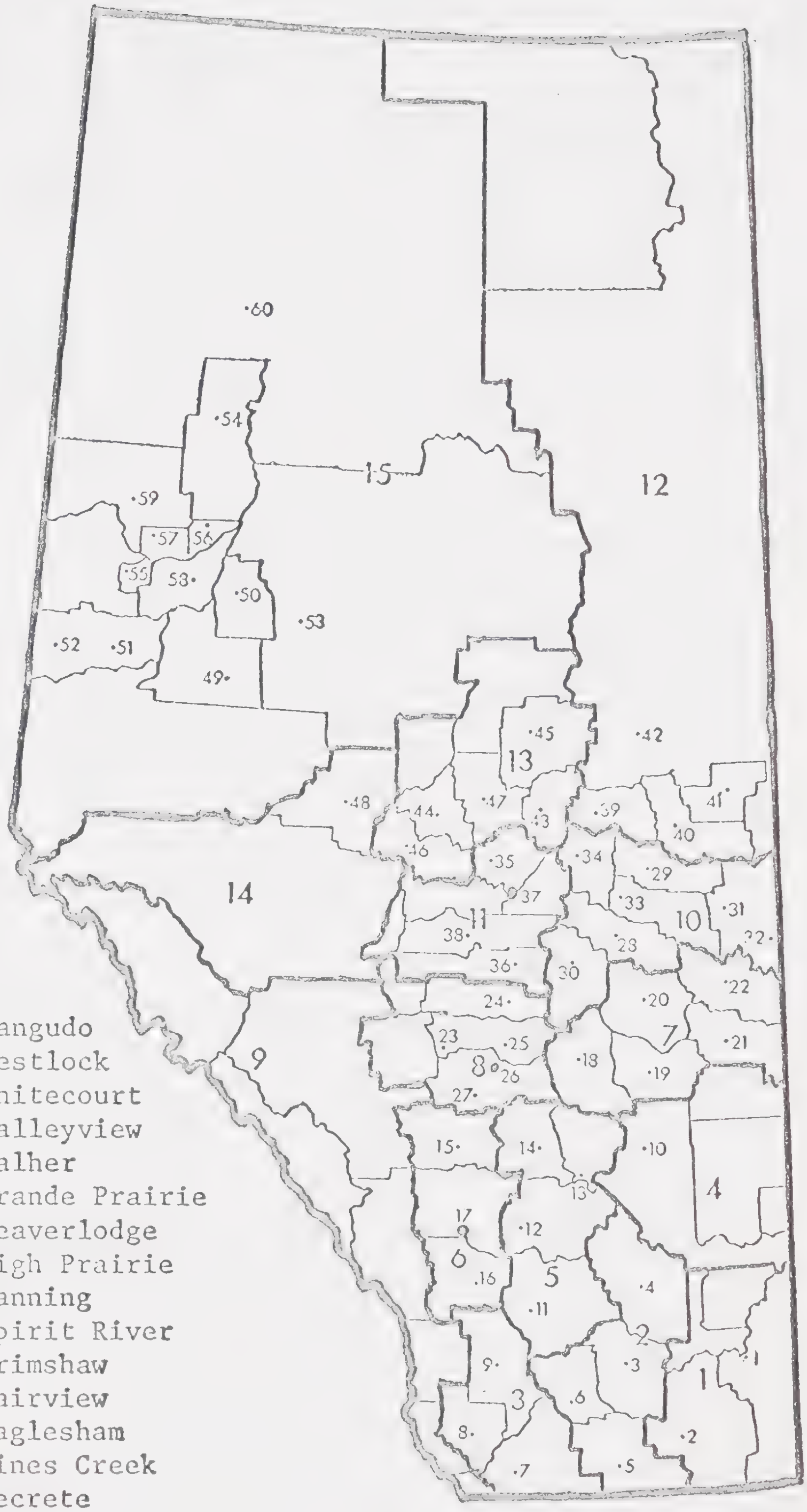


Figure 7

POTENTIAL ASSEMBLY LOCATIONS
(Also supply reference points)

areas would be served by these 60 locations, squares with diagonals representing sixty miles were centred on each location, with the diagonals of the square running north and south. A rectangular road grid system for the province was assumed. Given such a road system, the maximum distance any producer would be required to travel to an assembly site is 30 miles. If the producers were evenly distributed throughout the area served by the assembly site, the average delivery distance would be 15 miles (Figure 8).

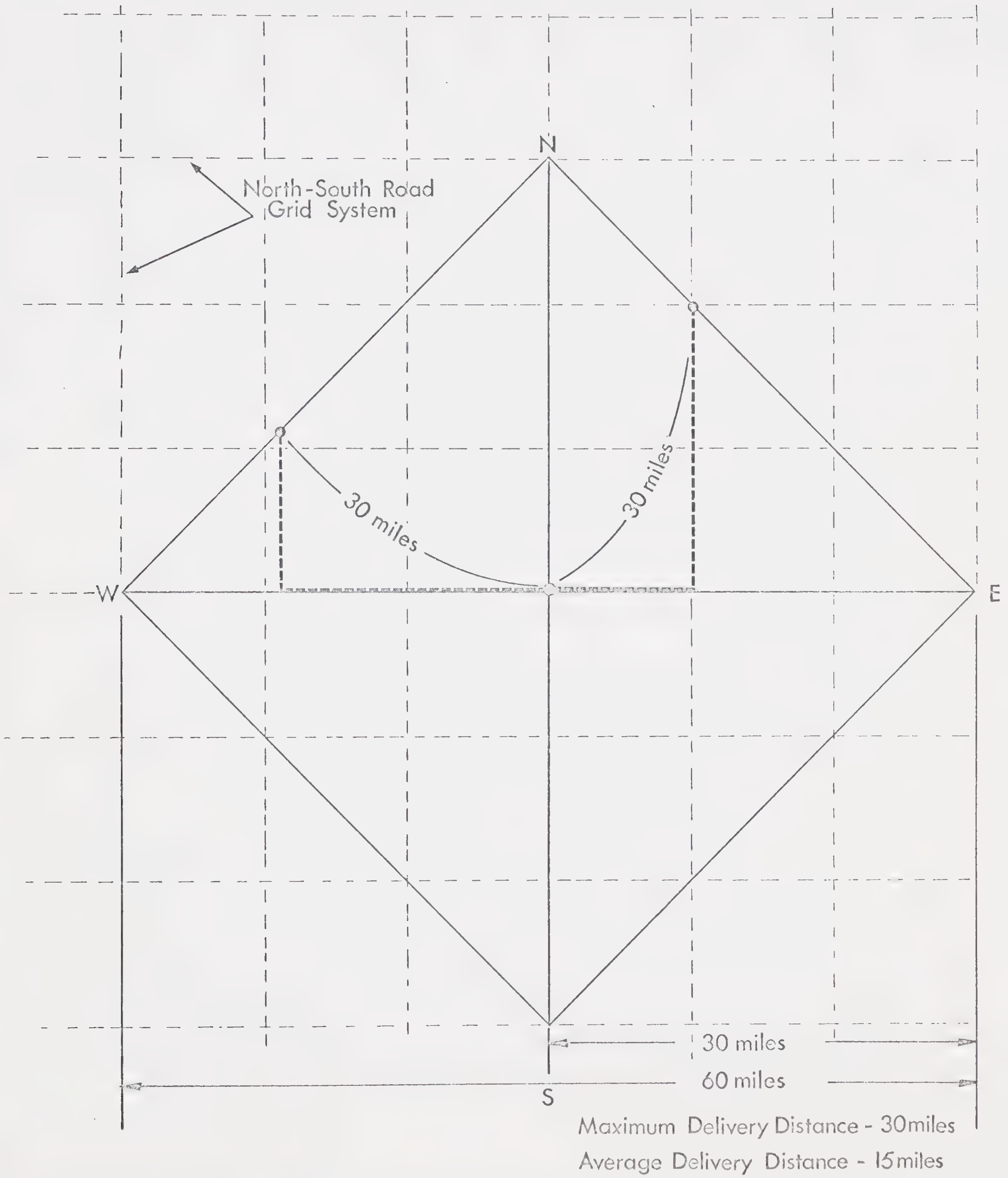
To finalize the supply analysis, each potential assembly location was assigned the volume of hogs shipped from the subdivision it represents. Where two potential assembly locations represent one subdivision, the volumes were assigned according to the shipments handled by all small surrounding assemblers in 1968.

Demand Analysis

One of the basic requirements for the spatial equilibrium model utilized in this study is that the amount of product supplied must equal that product's demand. For the first half of the analysis, the total supply at reference points was required to equal the total demand at the assembly points. Such a condition was fulfilled because assembly facilities were allowed enough flexibility to permit volume changes; at all times total supply equaled total demand. Volumes used at assembly and reference points equaled the quantities referred to in Table 11. In the last half of the analysis, the packing centres were utilized as demand nodes, and the assembly points functioned as supply nodes. In analyzing the demand for Alberta hogs in 1968, it was found that Edmonton handled 66 percent of the hogs graded, Calgary 25.3 percent, Red Deer 4.5 percent, and Lethbridge 4.2 percent. The total volumes were

Figure 8

PRODUCER DISTANCES FROM POTENTIAL ASSEMBLY LOCATIONS



1,116,339; 428,410; 80,292; and 71,911 respectively [2].*

The most important qualification for demand locations is that they be packing centres so that transportation and assembly costs may be minimized. Extra costs are incurred when hogs are assembled in the country, delivered to a centre, reassembled, and then shipped to a packing plant. Lethbridge was disregarded as a demand node because it is located in the low hog production area of the province and slaughter volume is only approximately 12,000 hogs per year. Most of the Lethbridge volume assembled was either sold to packers in Calgary or to out-of-province packers. The Lethbridge assembly volume was, therefore, transferred to Calgary for slaughter and distribution. Direct producer shipments would supply the Lethbridge packers.

Volumes used were as follows: Edmonton 927,502; Red Deer 67,581; and Calgary 416,205 (including 59,829 from Lethbridge). These volumes represent over 83 percent of the total graded carcass volume referred to above. This 83 percent is the established percentage of hogs handled by assemblers in Alberta (Table 5). Although the percentage delivered by assemblers varies at each packing centre, figures providing such information are not available.

The Transportation Matrix

Three sets of information were required for the development of the transportation matrix: road mileages between all potential assembly sites; trucking rates; and volumes supplied by each census subdivision. In the transportation matrix the potential assembly locations function as demand centres, the reference points as supply centres. Since

*These figures include Alberta hog carcasses graded out of the province.

trucking rates vary with distance, it was necessary to establish the distance between every supply centre and every assembly location. The result was a 60 x 60 mileage matrix. The mileages were obtained directly from road maps with the exception of a few that were calculated by converting air miles to road miles [9]. The shortest route was always chosen, and in most instances little use of secondary roads was required because the majority of the main highways run diagonally toward the city centres.

The freight levy per dressed hundredweight of pork is established by each individual trucker. Much variation exists in the rate depending on such factors as distance, size of loads, amount of competition, and back-hauls. In many instances trucker-assemblers vary trucking rates and at the same time change their assembly fee so that, in effect, their revenue per hog remains unchanged. Of the above factors, distance has the greatest effect upon the rate established. In a regression analysis applied to 42 of the potential assembly locations, it was found that distance accounted for 78.13 percent of the variation in freight rates. The regression equation is as follows:

$$\text{Rate} = .48 + \underset{(.00014)}{.00171}\ (\text{Distance})$$

The regression equation was not useful in establishing a uniform rate schedule based on distance because shorter distances would be overcharged. The rate schedule used in the study is based upon the present freight rates from 100 towns shipping to Edmonton. The towns were grouped according to their existing freight rates, and their mileages were recorded. A table was constructed to correlate mileage to a respective freight rate for each town (Table 12). A 60 x 60

Table 12

ESTIMATED FREIGHT RATES FOR ALBERTA HOGS, 1970

Miles	Rate Per Dressed cwt	Miles	Rate Per Dressed cwt
→ 15	.20	191 - 205	1.00
15 - 22	.25	206 - 250	1.05
23 - 30	.30	251 - 300	1.10
31 - 37	.35	301 - 325	1.15
38 - 45	.40	326 - 350	1.20
46 - 52	.45	351 - 375	1.25
53 - 60	.50	376 - 400	1.30
61 - 72	.55	401 - 425	1.40
73 - 85	.60	426 - 450	1.50
86 - 100	.65	451 - 500	1.60
101 - 115	.70	501 - 550	1.70
116 - 130	.75	551 - 600	1.80
131 - 145	.80	601 - 650	1.90
146 - 160	.85	651 - 700	2.10
161 - 175	.90	751 - 800	2.20
176 - 190	.95	800 +	2.30

Source: Information compiled from confidential industry sources.

matrix was formed showing the freight rates between all potential assembly sites and the supply points (Appendix D).

The final step in deriving the transportation cost matrix involved the multiplication of each transportation rate by the volumes supplied at each supply location. Each column in the matrix represents the costs of shipping the volume from every supply location to one assembly point in the province.

Analysis of Assembly Costs

At the present time the assembly rates established by assemblers vary from 10 cents to $1.50 per hog and have little correspondence to volume or capital investment. The type of facilities provided and the cost of operating vary considerably. The primary sources of data used for analyzing assembly operational costs were annual reports for cooperative assembly points in Alberta for 1968 and 1969. The size of the firms analyzed varied from those handling less than 2000 hogs per annum to those handling over 30,000 hogs. After dividing the firms into three size groups according to volumes handled, the fixed and variable costs were averaged. A labor rate of $2.00 per hour was utilized to add uniformity to the cost estimates. In all cases labor accounted for one-third to one-half of the handling cost per hog. For volumes greater than 30,000 hogs per year, cost estimates were extrapolated. The respective costs are listed in Table 13.

Assembly yards operate under conditions that differ from those of most businesses. Because labor is the largest cost and the hog supply is limited, most assembly yards only operate one or two days per week. As a result, fixed costs are relatively high because in most cases the facilities are idle more than they are in use. Given the unpredictable

Table 13

COST ESTIMATES FOR OPERATING HOG
ASSEMBLY YARDS*, 1970

	Number of Hogs Assembled	Operating Cost
1	→ 5000	950 + .33 (V)
2	5001 - 10000	950 + .218 (V)
3	10001 - 15000	950 + .168 (V)
4	15001 - 30000	1620 + .163 (V)
5	30001 - 50000	1620 + .142 (V)
6	50001 - 100000	2100 + .137 (V)
7	100001 - 150000 +	2100 + .111 (V)

*See Appendix E for further details.

fluctuations in hog supply, excess capacity is necessary to handle anticipated volumes. A large yearly volume is required to minimize per unit costs.

Since size, the utilization of facilities, and the amount of labor used can vary greatly, only three sizes of assembly yards were used. Fixed assets for the three sizes were $7,000, $12,000, and $15,000. Referring to Table 13, numbers 1, 2, and 3 used the smallest size of facilities; numbers 3 and 4 used the medium sized facilities; and numbers 6 and 7 used the largest size of facilities.

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[11] __________. Ibid., p. 482.

CHAPTER IV

APPLICATION OF THE MODEL AND INTERPRETATIONS

Two basic approaches to the long-run spatial model may be used. These are referred to as the iterative expansion approach and the iterative elimination approach [1]. The objective of each method is to minimize transportation costs after which assembly operational costs can be computed. The summation of the two costs results in the combined cost for moving hogs from producers through assembly points. The transportation cost from assemblers to packers can then be added to yield the total combined cost function.

The method used in this study is the iterative expansion (IEXPA) approach, which results in a suboptimal solution. In the first iteration the IEXPA method selects one assembly location to minimize transportation costs. In the next iteration a second assembly location is chosen to minimize transportation and assembly costs with respect to the site chosen previously. Assembly sites are added one by one, always conditional upon the locations of previously selected sites. Stated differently, the location of the K^{th} assembly site is always conditional upon the location of the (K-1) assembly sites. In each iteration one more location was chosen, and the number of hogs to be assembled and the census subdivisions to be served by each yard were indicated. The program was designed to calculate the operating costs for each assembly yard according to volumes handled in each iteration; consequently, the combined cost could be calculated.

The other method is the iterative elimination approach. In this

study one would start with 60 assembly locations and eliminate the most uneconomical locations one at a time until the suboptimization point is reached. The suboptimal solution is the point at which the total combined cost function is at its minimum.

An optimal solution can be derived using the combinations approach (pp. 45-46). The IEXPA method leaves (K-1) locations fixed when considering the K^{th} location, while the combinations method allows (K-1) to be variable when solving for K. For example, in chosing a tenth assembly location every conceivable combination for ten locations ($_{60}C_{10}$) will be considered. With 60 potential locations, the combinations approach is computationally infeasible.

Transportation Costs as a Function of the Number of Assembly Locations

Producer to Assembler Costs

Producer to assembler freight costs account for the largest proportion of transportation costs.* Due to the decentralizing effect of adding more assembly locations, producer to assembler transportation costs decrease. The model minimized the transportation cost with respect to volumes shipped from production areas. Initially the cost function decreases rapidly as additional assembly locations are added; later the rate of decline decreases as the location numbers correspond more closely to the number of production centres. Trucking rates used to analyze producer to assembly transportation costs were standardized by using the trucking rate scale explained in Chapter II.** Standardization of

*Producer to assembler freight costs are synonymous with production reference point to assembler freight costs.

**Estimated commercial trucking rates were used for producers to add some degree of uniformity to producer trucking costs.

producer's trucking rates was necessary since the circumstances under which producers deliver hogs vary from one individual to the next.

Results from using the spatial equilibrium model (LRSM) indicated the producer to assembler transportation cost function to be convex and decreasing with the addition of assembly locations. The above statement can be demonstrated through the use of first and second differences. The first differences are negative; the second differences are positive. Producer (production reference point) to assembler transportation costs were $1,489,023 when one assembly location was utilized and these costs decreased as assembly locations were added. No cost was included to allow for the distance from the production reference point in each subdivision to the producers in that area. The numerical results are presented in Table 14 and illustrated in Figure 9.* The model selected Wetaskiwin as the first assembly location because it is the topological production centre using the 60 potential assembly locations.

Assembler to Packer Costs

Assembler to packer transportation costs were calculated through application of the linear programming transportation model. The transportation costs to packing centres increased as assembly locations were added. The minimum transportation cost solution would naturally occur when an assembly location is allocated to each packing centre. However, transportation cost estimates were necessary for each iteration so that the total combined cost function could be formed. By using the transportation model, the assembler to packer shipping costs were minimized

*Figure 9 is not a continuous function because of the change in integer input on the vertical axis.

Table 14

TRANSPORTATION AND ASSEMBLY COSTS WITH RESPECT TO THE NUMBER OF ASSEMBLY LOCATIONS

No. of Assembly Pts.	Operating Costs	Transportation Cost Prod. - Assblr.	Assblr. - Pack.	Total Comb. Cst.
1.	$158753	$1489023	$1106632	$2754408
2.	160853	1215352	663197	2039402
3.	162953	1048630	310356	1521939
4.	165053	913565	506763	1585381
5.	167153	785605	533244	1486002
6.	169253	695396	673817	1538466
7.	173475	608954	808497	1590926
8.	175575	537485	938104	1651164
9.	180009	488853	978394	1647256
10.	184063	450458	1015228	1649749
11.	186163	421225	1069953	1677341
12.	191277	393533	1084757	1669567
15.	207798	321741	1048181	1577720
20.	218716	232476	1065119	1516311
25.	228680	165907	1079922	1474509
30.	240668	112826	1080134	1433628
31.	243080	104826	1081201	1429107
32.	248300	96893	1089028	1434221
33.	250687	89038	1090432	1430157
34.	252417	81810	1090432	1424659
35.	254267	75510	1092007	1421784
36.	256097	69838	1092890	1418825
37.	256936	64465	1093425	1414826
38.	257801	59235	1098329	1415365
39.	259767	54198	1097841	1411806
40.	263884	49967	1097841	1411692
41.	265241	45816	1099703	1410760
42.	266068	41799	1101041.	1408908.

Table 14 (Continued)

No. of Assembly Pts.	Operating Costs	Transportation Cost Prod. - Assblr.	Transportation Cost Assblr. - Pack.	Total Comb. Cst.
43.	$268231	$37956	$1103009	$1409196
44.	269959	34142	1103518	1407619
45.	271139	30434	1105001	1406574
46.	272396	26778	1106814	1405988
47.	273740	23350	1108677	1405767
48.	275121	19941	1108677	1403739
49.	277523	16641	1108677	1402841
50.	279140	13349	1109875	1402364
51.	281247	10399	1110224	1401870
52.	283038	8440	1111832	1403310
53.	284875	6529	1112054	1403458
54.	286243	5027	1112429	1403699
55.	287612	3724	1112906	1404242
56.	289392	2536	1113159	1405087
57.	290595	1352	1113316	1405263
58.	291680	624	1113050	1405354
59.	292630	64	1113994	1406688
60.	293612	0	1114058	1407670

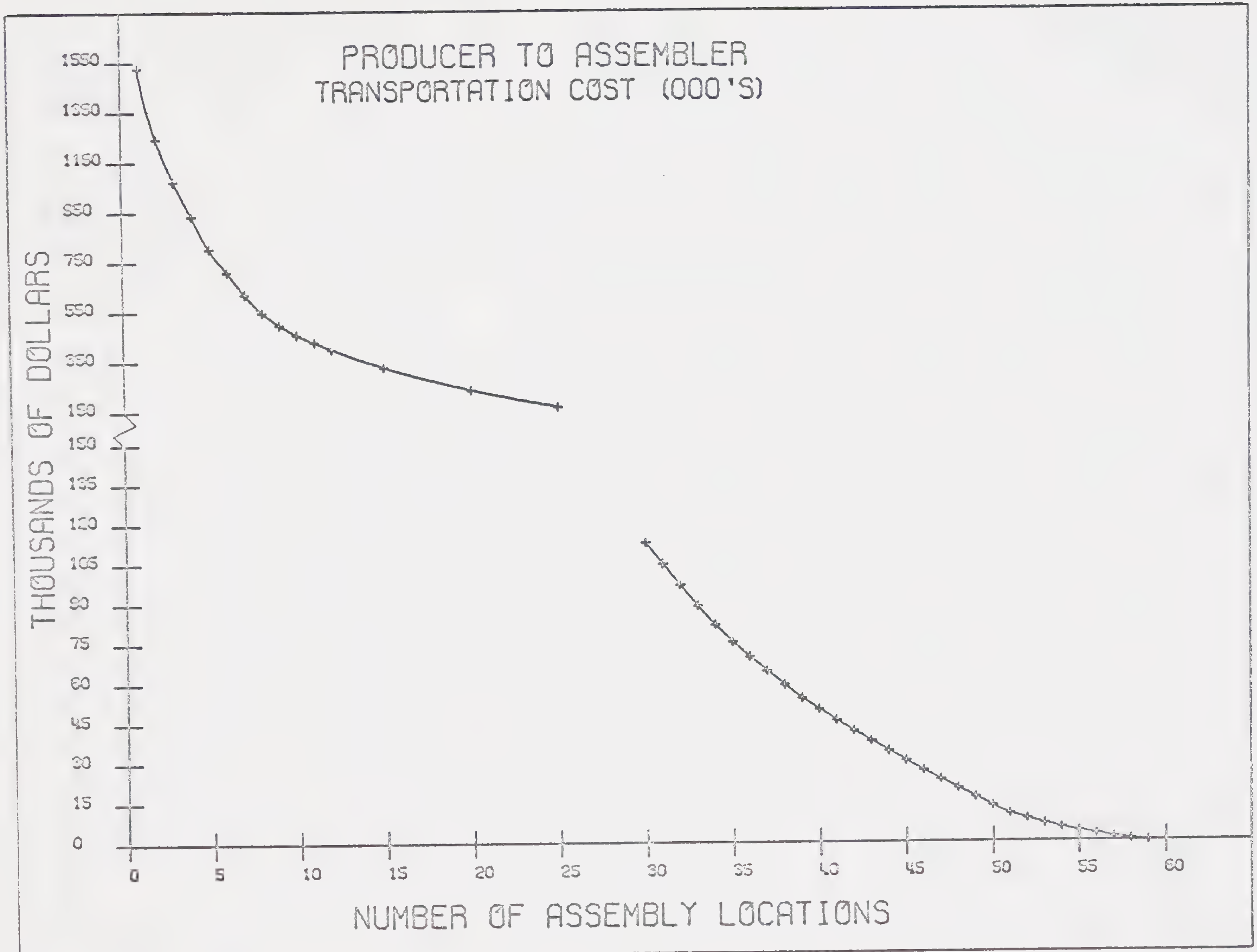

PRODUCER TO ASSEMBLER
TRANSPORTATION COST (000'S)
THOUSANDS OF DOLLARS
1550
1350
1150
950
750
550
350
150
150
135
120
105
90
75
60
45
30
15
0
0
5
10
15
20
25
30
35
40
45
50
55
60
NUMBER OF ASSEMBLY LOCATIONS

Figure 9

for the assembly locations in each iteration. The transportation model specified the volumes to be shipped to each packing centre from the assembly locations previously calculated by the LRSM.

The numerical results are presented in Table 14 and illustrated in Figure 10. As Wetaskiwin, Calgary, and Edmonton were chosen in the first three iterations, the transportation costs decreased. For every location added after Edmonton, the assembler to packer transportation cost increased as assembly volumes were moved from packing centres to country locations. It should be noted that Lethbridge was chosen before Red Deer as an assembly centre because a southern location would minimize total transportation costs more than locations in the central or northern portions of the province. After the addition of the third assembly location, assembler to slaughter centre transportation costs ranged from \$506,763 for the fourth location to \$1,114,058 for the sixtieth. Locations in the order of their selection are listed in Appendix G.

Assembly Costs as a Function of the Number of Assembly Locations

In general, assembly costs will increase as the number of assembly locations is increased. As stated in Chapter III, the increase will be equal to the value of the intercept (fixed costs) plus any increase caused by a change in the variable cost rate per hog as each location is added. With the addition of each assembly location, volumes assembled were changed in one or more of the previously selected sites. Given these volumes, the assembly operational costs were calculated for each iteration. Costs were estimated for assembly location sizes ranging from the extreme of one location handling all the hogs in Alberta (first iteration) up to 60 locations (last iteration) sharing the Alberta volume.

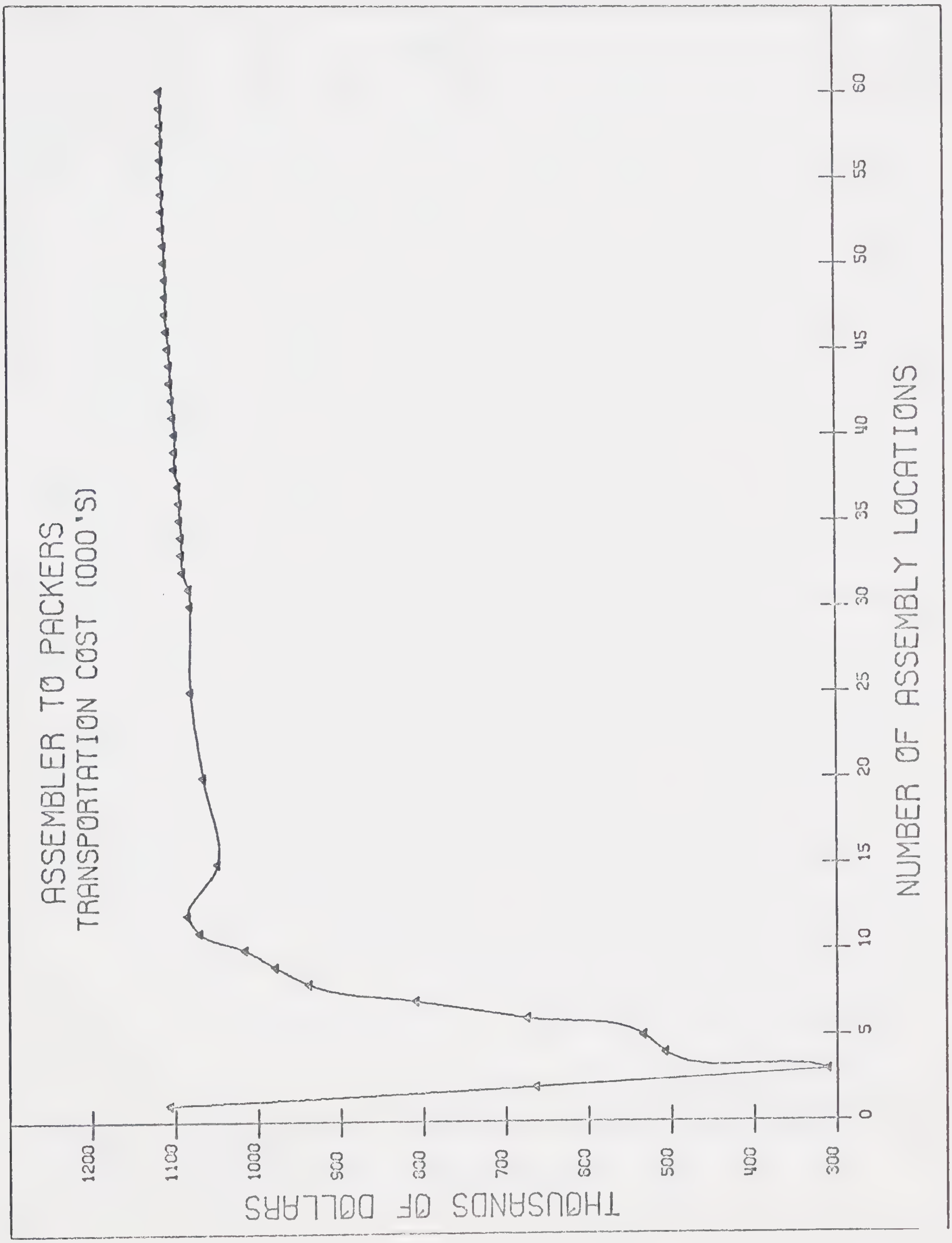

ASSEMBLER TØ PACKERS
TRANSPØRTATIØN CØST (000'S)
THØUSANDS ØF DØLLARS
NUMBER ØF ASSEMBLY LØCATIØNS
1200
1100
1000
900
800
700
600
500
400
300
0
5
10
15
20
25
30
35
40
45
50
55
60

Figure 10

Accuracy of the cost estimations for the first iterations may be questioned for there are no firms in existence with such large volumes. However, the diseconomies of scale argument is a dubious one. In a situation using only one assembly location, more than one assembly yard would probably exist. If so, the total assembly costs would increase by the additional fixed cost for each yard added. As extra assembly facilities were added, the volumes assembled corresponded more closely to the volumes used in making the assembly cost estimates for the analysis. Some caution should be used when analyzing the conclusions of the first few iterations, for it is unrealistic to assume that hogs would be shipped past a packing centre to an assembly location and then shipped back to the packing centre for slaughter.

Empirical results for assembly operating costs ranged from $158,753 for a single location up to $293,612 for 60 locations (Table 14). The cost function is illustrated in Figure 11. Since the cost estimates used for assembly operations were derived from averages and extrapolation, a sensitivity analysis was performed on assembly operational costs. First, fixed costs were raised 10 percent and then lowered 10 percent. Next, fixed and variable costs were raised 10, 20, and 30 percent and then lowered by the same percentages. Of the above changes, only the 30 percent increase and decrease in fixed and variable costs changed the number of assembly locations in the solution. The results are recorded in Appendix F. The conclusion drawn from the sensitivity analysis is that assembly operational costs can vary significantly without changing the number of locations in the least-cost solution.

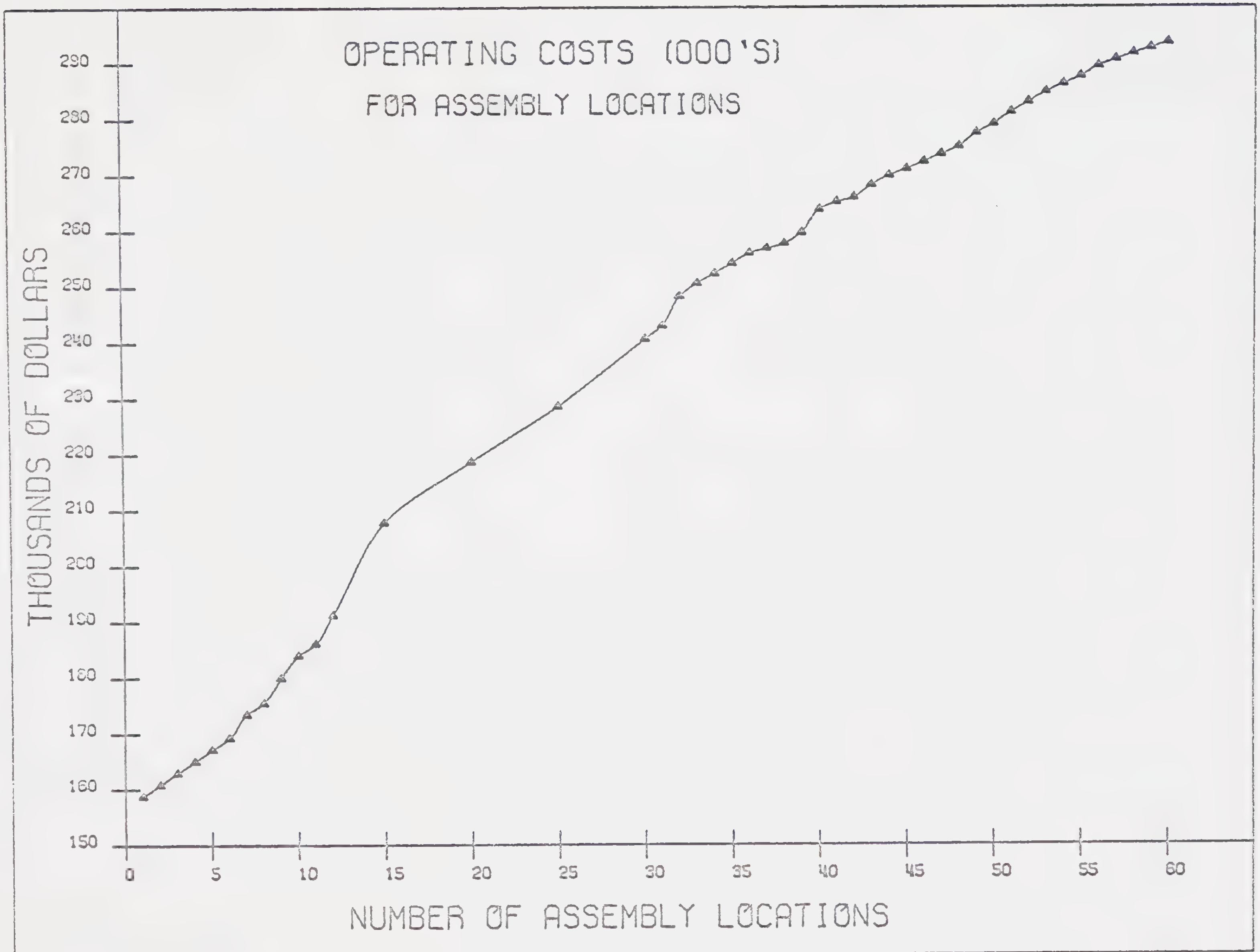
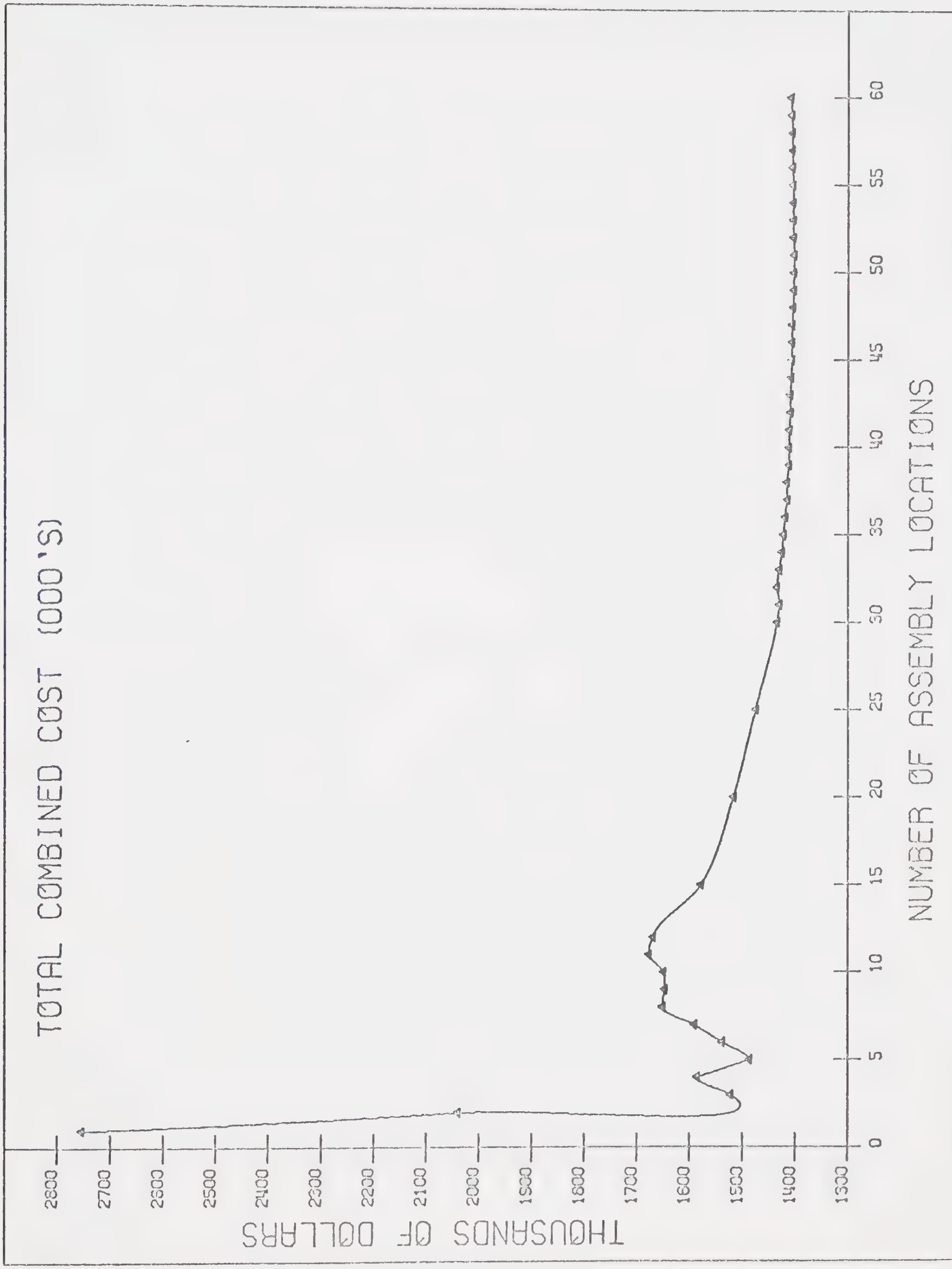

OPERATING COSTS (000'S)
FOR ASSEMBLY LOCATIONS
THOUSANDS OF DOLLARS
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
0
5
10
15
20
25
30
35
40
45
50
55
60
NUMBER OF ASSEMBLY LOCATIONS

Figure 11

Total Combined Costs as a Function of the Number of Assembly Locations

The total combined cost function was obtained by the summation of the producer to assembler cost, the assembly operating cost, and the assembler to packing centre cost for each iteration. The assembly operating cost function was positive sloping, and the assembler to packer transportation cost function increased after the addition of the third assembly location. The producer to assembler cost function had a negative slope. As long as the increase in the summation of the increasing cost functions was less than the decrease in the producer to assembler cost function, the TCC function could be expected to decline with the addition of assembly locations. The point where the TCC function reached a minimum (where the slopes of the three functions were equal) was the suboptimal solution because the IEXPA method was used in this study. Although an optimal solution was not derived, the suboptimal solution was considered accurate. In a previous study performed by Warrack, it was concluded that when the TCC curve is relatively flat in the solution area, a small change in plant numbers or in location patterns would have relatively little effect on total costs [2].

Numerical results of the TCC function are listed in Table 14 and illustrated in Figure 12. The TCC decreased for the first three assembly locations because hogs were assembled at packing centres or locations most convenient to packing centres. On the fourth iteration, Lethbridge was added, and as a result of the decentralizing effect, the assembler to packer transport cost caused the TCC function to increase. Red Deer was the next location selected; because Red Deer is a packing centre, the TCC decreased. The TCC function continued to increase up to the eleventh location as assembly volumes were relocated from packing centres


TØTAL CØMBINED CØST (000'S)
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1800
1700
1600
1500
1400
1300
0
5
10
15
20
25
30
35
40
45
50
55
60

Figure 12

to rural areas. From the eleventh location the function decreased to the minimum solution using 51 locations and then increased as additional assembly locations became uneconomical. Total combined costs varied from $2,754,408 for one assembly location to $1,401,870 for the least-cost solution.

The least-cost solution in the TCC function utilized 51 of the 60 potential assembly locations. The locations eliminated are illustrated by asterisks in Figure 13. The locations eliminated by the model either had small volumes or high transportation costs. In the last 20 assembly locations the TCC changed very little with the addition of each assembly centre. Each assembly location added before the least-cost solution was obtained resulted in a reduction in the TCC and at the same time increased the convenience to the producers. After the addition of the fifty-first location, the TCC increased, and it was considered economical for producers to haul their hogs some extra distance. The volumes to be handled by each assembly location in the least-cost solution and the packing centres to which they should deliver to minimize transportation costs are depicted in Table 15.

Interpretation of Results

The assembly organization suggested in the least-cost solution is markedly different from the existing hog assembly system. The solution distributes Alberta's hog volume among 51 assembly locations, while the present system utilizes over 300 locations with approximately 500 assemblers. Table 6 (Chapter II) indicates the degree of concentration and the relative volumes of assembly locations in the existing system. Most of the census subdivisions have many assembly locations. Average

1. Medicine Hat
2. Foremost
3. Vauxhall
4. Brooks
*5. Warner
6. Lethbridge
7. Cardston
8. Pincher Creek
9. Claresholm
*10. Hanna
*11. Vulcan
*12. Strathmore
13. Drumheller
14. Three Hills
15. Didsbury
*16. High River
17. Calgary
18. Stettler
19. Castor
20. Killam
21. Czar
22. Wainwright
23. Eckville
24. Ponoka
25. Lacombe
26. Red Deer
27. Innisfail
28. Holden
29. Two Hills
30. Camrose
31. Vermilion
32. Lloydminster
33. Vegreville
34. Lamont
35. Morinville
36. Wetaskwin
37. Edmonton
38. Thorsby
39. Smoky Lake
40. St. Paul
41. Bonnyville
42. Lac La Biche
43. Thorhild
44. Barrhead
45. Athabasca
46. Sangudo
47. Westlock
*48. Whitecourt
49. Valleyview
50. Falher
51. Grande Prairie
52. Beaverlodge
53. High Prairie
54. Manning
*55. Spirit River
56. Grimshaw
57. Fairview
*58. Eaglesham
*59. Hines Creek
60. Lecrete

Figure 13

ASSEMBLY LOCATIONS SELECTED IN THE LEAST-COST SOLUTION

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* Locations eliminated.

Table 15

LEAST-COST SOLUTION: LOCATIONS, VOLUMES, AND PACKING CENTRES USED

Assembly Location	Volume	Reference Pts. Served (Location No.)	Packing Centre
1. Medicine Hat	3,991	1	Calgary
2. Foremost	5,032	2	"
3. Vauxhall	15,238	3	"
4. Brooks	21,512	4	"
6. Lethbridge	92,095	6 and Warner	"
7. Cardston	6,001	7	"
8. Pincher Creek	4,944	8	"
9. Claresholm	14,860	9 and Vulcan	"
13.Drumheller	4,889	13	"
14.Three Hills	25,376	14	"
15.Didsbury	22,681	15	"
17.Calgary	151,697	17, Strathmore, High River	"
18.Stettler	28,149	18	Edmonton
19.Castor	8,188	19 and Hanna	"
20.Killam	30,722	20	"
21.Czar	8,925	21	"
22.Wainwright	11,137	22	"
23.Eckville	7,264	23	"
24.Ponoka	31,838	24	"
25.Lacombe	65,301	25	"
26.Red Deer	109,328	26	Ed. - 30,333 Cal. - 11,414 R.D. - 67,581
27.Innisfail	36,475	27	Calgary
28.Holden	16,063	28	Edmonton
29.Two Hills	25,098	29	"
30.Camrose	69,331	30	"
31.Vermilion	29,888	31	"
32.Lloydminster	10,500	32	"

Table 15 (Continued)

Assembly Location	Volume	Reference Pts. Served (Location No.)	Packing Centre
33.Vegreville	34,429	33	Edmonton
34.Lamont	21,218	34	"
35.Morinville	21,154	35	"
36.Wetaskiwin	43,320	36	"
37.Edmonton	96,155	37	"
38.Thorsby	17,417	38	"
39.Smoky Lake	16,295	39	"
40.St. Paul	41,117	40	"
41.Bonnyville	26,241	41	"
42.Lac La Biche	6,106	42	"
43.Thorhild	5,681	43	"
44.Barrhead	54,937	44	"
45.Athabasca	19,201	45	"
46.Sangudo	27,866	46 and Whitecourt	"
47.Westlock	42,004	47	"
49.Valleyview	8,989	49	"
50.Falher	8,962	50 and Eaglesham	"
51.Grande Prairie	20,835	51	"
52.Beaverlodge	12,604	52	"
53.High Prairie	4,370	53	"
54.Manning	5,919	54	"
56.Grimshaw	5,830	56	"
57.Fairview	10,599	57, Spirit River, and Hines Crk.	"
60.Lacrete	3,516	60	"

assembly and average transportation costs for the existing assembly system were estimated based upon the volume of hogs assembled and transported for sale through The Board in April 1970. The average costs per hog were: assembly, 44 cents; transportation, 96 cents; for a total of $1.40 per hog.

In most instances only one assembly location was allotted to each census subdivision for this study. Exceptions can be noted in Figure 13. Average cost results were: assembly, 19.9 cents; transportation, 79.4 cents; for a total of 99.3 cents per hog. Table 16 presents the solution's average assembly and average transportation costs as a function of the number of assembly locations. The total cost per hog decreases rapidly for the first 30 locations, and then the rate of decline slows as the lower portion of the total combined cost function is reached.

A sensitivity analysis (Page 72) was applied to the cost estimates used for assembly operations. The conclusion was that the cost estimates were sufficiently accurate, over a 20% change in assembly rates was required to alter the number of assembly locations in the suboptimal solution. The results also imply that transportation costs were the primary factor influencing the number of assembly locations.

The effect of using fewer assembly locations decreased assembly and transportation costs due to the economies of size existing in assembly operations and to the removal of much duplication in assembly and trucking facilities. If only 51 locations were utilized, competitive pricing in both the assembly and trucking businesses would decline. Therefore, the distribution of any benefits from lower assembly and trucking costs would depend partly on how a consolidation plan was administered and partly on the distribution of (market) bargaining power.

Table 16

AVERAGE ASSEMBLY AND TRANSPORTATION COST PER HOG AS A FUNCTION OF THE NUMBER OF ASSEMBLY LOCATIONS

No. of Assembly Locations	Operating Cost/Hog	Producer to Assembler Transport Cost/Hog	Assembler to Packer Transport Cost/Hog	Average Cost/Hog
	($)	($)	($)	($)
1	.112	1.05	.784	1.95
10	.13	.319	.719	1.17
20	.155	.165	.755	1.07
30	.170	.08	.765	1.01
40	.187	.035	.778	1.00
50	.197	.009	.786	.993
60	.208	0	.789	.997

A consolidation plan presumably would first need the approval of the hog producers, after which The Board would seem the most likely administrator. The Board has provided producers with a source of potential bargaining power which could be utilized to improve market efficiency.

References Cited

[1] WARRACK, A.A. and L.B. Fletcher. Location and Efficiency of the Iowa Feed-Manufacturing Industry. Agriculture and Home Economics Experiment Station Research Bulletin 571. Ames, Iowa: Iowa State University of Science and Technology, March 1970, pp. 497-498.

[2] __________. *Ibid.*, p. 502.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

In 1965, the total retail value for Alberta pork was approximately $168 million, consisting of about $77 million to producers plus $91 million for assembly, processing, and distribution [1]. Hog production is also important to the Alberta farm economy because it provides an outlet for surplus grains and is often supplementary to the farm operation. Census data indicates a definite trend toward specialization; however, nearly half of Alberta's hogs are still produced on farms marketing less than 62 hogs per year (2). The province's pork output is much the same today as it was 30 years ago. As a result, Alberta has descended from the largest pork producer in Canada to the third largest.

If the Alberta pork industry is to experience any growth in the future, it must maintain or increase its share of the Canadian market and must also anticipate expansion in United States and foreign markets. To compete effectively in these markets, Alberta must be prepared to supply pork at competitive prices. In other words, the Alberta pork industry must become efficient enough to absorb any freight costs and still provide a quality product cheaper than producers in these markets. Alberta's competitive position can be strengthened through improvements in production and marketing efficiency.

The focal point of this study concerned market efficiency: to reduce the cost of assembling and shipping hogs from the producer to the packing centre. It was hypothesized that such a cost reduction

could be achieved through the reduction of the number of assembly locations.

The objectives were (1) to determine assembly costs as a function of the number of hog assembly locations, (2) to determine transportation costs as a function of the number of hog assembly locations, and (3) to determine the optimum number, size, and location of hog assembly locations in Alberta based on the information established in the first two objectives. It was not the purpose of this study to imply that all assembly and transportation costs were too high, but to emphasize that the average of each of these costs could be lowered.

The demand and supply analyses were based upon figures for 1968, the assumption being that this particular year would reflect the general distribution of the swine industry in the long-run. Enough flexibility was allowed in assembly facilities to permit some deviation from the 1968 demand and supply analyses. In addition, the location of slaughtering centres was taken as given. Transportation cost information for distances of up to 350 miles was obtained. However, it was necessary to estimate transportation costs for up to 800 miles. A stabilizing factor was that existing transportation rates were available for the relevant solution range.

Assembly operational costs were obtained from annual reports for assembly facilities ranging in capacity from 2,500 to 30,000 hogs per year. From these reports, operating costs were extrapolated for assembly facilities with volumes of up to 100,000 hogs per year. Because there was considerable variation in wage rates, professional fees, capacities, and fixed investments, the operating costs in the annual reports had to be standardized to some degree. Background information

in the study was limited by a lack of provincial import-export data.

Application of the model removed the effects of competition from the assembly and trucking operations by utilizing 51 assembly locations instead of the over 300 presently existing locations. Each assembly location was allotted the hogs from a specific area or areas, and the assembly fees and transportation rates were standardized according to volume and distance respectively. It was assumed that increases in the number of assembly locations would result in higher rates due to a reduction in operational efficiency. The actual transportation cost from each producer to the nearest assembly location was not considered. Such a cost would be virtually impossible to calculate because of the variety of conditions under which producers deliver their hogs to assembly centres. Based on the assumption that hog production is distributed evenly throughout each division, a supply reference point was located at a trading centre near the middle of each census sub-division. Using these reference points, the distance between most hog producers and an assembly location averaged approximately fifteen miles.

The regional hog marketing data was obtained from the Swine Data Bank, 1968, Department of Agricultural Economics and Rural Sociology, University of Alberta. The demand estimates were calculated from information in the Annual Livestock Market Reports published by the Canada Department of Agriculture. An Alberta transportation matrix was developed giving mileages between all potential assembly locations. By applying transportation rates, a transportation cost matrix was developed. Assembly operating costs were calculated from annual livestock cooperative reports.

In the solution procedure three cost functions were calculated,

each with respect to the number of assembly locations. The transportation cost function from production reference points to assemblers and the assembly operating cost function were both calculated with the long-run spatial model. The vertical summation of these two functions resulted in the combined cost function. The linear programming transportation model was used to calculate the assembler to slaughter centre transportation cost for each set of locations at each point on the combined cost function. The vertical summation of the transportation cost and the combined cost functions resulted in the total combined cost function. The least-cost solution was at the minimum point on the total combined cost function. A suboptimization procedure was used in the long-run spatial model to calculate the least-cost solution. The computational burden encountered in reaching the optimum combinatorial solution would have made this study impossible.

Results from the long-run spatial model showed the producer to assembler transportation cost function to be decreasing and convex to the origin. As the last potential assembly location was added, producer to assembler transportation costs became zero because assembly centres and production reference points are synonymous. Producer to assembler costs are based on the distance between assembly locations and production reference points. Producer to assembler transportation costs ranged from a high of $1,489,023 using one assembly location to no cost when 60 locations were utilized. The assembly operational cost function increased with the addition of each assembly location by the value of the intercept (fixed costs) plus any increase caused by a change in the variable cost rate per hog. Total assembly operational costs varied from $158,753 for one location to $293,612 for 60 locations.

The assembler to slaughter centre transportation cost function was calculated with the transportation model. The function decreased for the first three locations because hogs were assembled close to the packing centres. Then the transportation cost increased as assembly locations became more decentralized. Assembler to slaughter centre transportation costs varied from $506,763 for the fourth assembly location to $1,114,058 for the sixtieth location.

By vertical summation of the three cost functions (producer to assembler transport cost, assembly operational cost, and assembler to slaughter centre transport cost), the total combined cost function was obtained. For the first 11 assembly locations selected by the spatial model, the total combined cost function fluctuated. This fluctuation was due largely to the effect of the assembler to slaughter centre transportation cost function. After the addition of the eleventh assembly location, the total combined function declined to the least-cost solution, which used 51 assembly locations. The rate of decline was rapid up to the addition of the thirtieth assembly location. The total combined cost then decreased slowly from the thirtieth location to the fifty-first, after which the cost function increased gradually. Although the cost savings were small for the last 20 assembly locations, their utilization was justified on the basis of cost savings and convenience to producers. However, addition of assembly locations beyond the least-cost solution (51 locations) is arbitrary because costs are increasing and assembly volumes are small. In other words, the extra cost per hog would likely outweigh the convenience created by additional assembly locations. The total combined costs varied from $2,754,408 for one assembly location to $1,401,870 for the least-cost

solution.

Conclusions

Observation of the three cost functions forming the total combined cost function showed that assembly operating costs had the least influence on the suboptimal (least-cost) solution. This conclusion was substantiated by a sensitivity analysis which showed that over a 20 percent change in both fixed and variable assembly costs was required to change the number of assembly locations in the least-cost solution. The shape of the total combined cost function was determined largely by the increasing cost of assembler to slaughter centre transportation, conditioned by the decreasing cost of producer to assembler transportation. Other factors causing the total combined cost function to decrease were the reduction of duplication in assembly and trucking facilities.

Based on the assumptions made, the least-cost solution suggested a considerable reduction in the number of assembly locations. Fifty-one selected assembly locations replaced over 300 locations using approximately 500 assemblers. High density production areas experienced a greater reduction in existing assembly location numbers than did areas of low density production. The study resulted in lower average assembly and transportation costs per hog than are incurred under the existing system. Potential savings per hog could be about 24 cents for assembly costs and 16 cents for transportation costs (Table 17). Based on the 1968 assembly volume, such savings would amount to over half a million dollars reduction in assembly and transportation costs. These savings do not include possible economies created in the transportation system as a result of more concentrated volumes. With fewer assembly locations the possibility of controlling the flow of hogs to packing centres would

Table 17

AVERAGE ASSEMBLY AND TRANSPORTATION COST ESTIMATES PER HOG FOR THE PRESENT ASSEMBLY SYSTEM AND FOR THE LEAST-COST SOLUTION*

Operation	Present (cents)	Least-Cost (cents)
Assembly	44	19.9
Transportation	96	79.4
TOTAL	$1.40	$0.99

*Present assembly and transportation costs are based upon 1970 data.

increase. Under the present assembly system packers always have an uncertain supply of slaughter hogs. By regulating the daily and weekly flow of hogs, operational efficiency could be increased at the processing level. Distribution of any benefits created by a consolidation plan would depend partly on how the plan was administered and partly on the distribution of bargaining power in the market. Hopefully, all participants in the market channel would share the cost savings and any benefits created by increased operational efficiency.

From the empirical results of this study, it was concluded that considerable reduction in assembly facilities could be justified. A trade-off does exist between the cost minimization goal and personal convenience. However, the cost savings resulting from the utilization of only 51 assembly locations should offset most of the inconvenience created for individual producers. The maximum distance most producers would have to travel to the nearest assembly location would be 30 miles, and the average distance would be approximately 15 miles.

The approval of producers and the government would be required before any plan for the reduction of assembly locations could be initiated. If a consolidation plan were approved, The Board would be the most plausible administrator because it represents the hog producers. The method and rate of change-over from the present system should be a producer decision, for producers are paying for all assembly and transportation costs. The change-over could be rapid; or else gradual, allowing existing facilities to depreciate out. An assembly consolidation plan would provide cost savings as a result of increased operational efficiency in the assembly and transportation processes. Also, the possibility for improved operational efficiency in processing

would increase. Improvements in operational efficiency would have no negative effects on exchange efficiency; therefore, overall marketing efficiency would increase. It is through such cost reductions and improvements in market efficiency that the Alberta pork industry may improve its competitive position.

Additional research studies could supplement this study. An analysis of economies of size for livestock trucking would be useful, as well as a study to establish the feasibility of regulating the producer to packer flow of hogs. A more complete study of economies of scale in hog assembly locations could be beneficial. As the trend toward specialization increases, a location study for hog production units relative to feed supply, transportation, and packing centres could be useful. Looking to the future, a location analysis and study of economies of size for packing and processing plants would provide useful guidelines for the swine industry in Alberta. Decentralization of the meat packing industry in Alberta can be expected, as is the present trend in the United States. This decentralization is the result of economies of size created at smaller plant volumes through the use of new technology and specialization. The smaller, efficient slaughter units locate in areas of high production density near trade centres where labor and other necessary inputs are available.

Results of this study may have been improved through an analysis of transportation costs from producers to the nearest assembly location. Also, a larger sample of cost data from assemblers might have influenced the assembly operational costs used in the study. To obtain the above transportation and assembly cost information, two sets of questionnaires would have been required.

References Cited

[1] MANNING, T.W. Performance of the Hog Marketing System in Alberta. Agricultural Economics Research Bulletin 4. Edmonton: University of Alberta, Department of Extension, July 1967, p. 1.

[2] MEAT PACKERS COUNCIL OF CANADA. Meat. Islington, Ontario: Meat Packers Council of Canada, 1969-70, p. 4.

APPENDICES

APPENDIX A

VALUE OF HOGS PRODUCED IN CANADA, 1960-69

Year	Total Farm Income* (thousands)	Income from Hogs (thousands)	% from Hogs
1960	2,776,723	277,590	9.9
1961	2,951,862	317,745	10.7
1962	3,101,788	312,221	10.0
1963	3,197,881	306,646	9.5
1964	3,490,896	321,574	9.2
1965	3,805,519	378,754	9.9
1966	4,232,230	422,193	9.9
1967	4,379,038	408,283	9.3
1968	4,393,300	408,000	9.3
1969	N.A.	423,081	-

Source: Canada Dominion Bureau of Statistics, Canada Yearbook (Ottawa: Queen's Printer, 1960-69).

*excludes supplementary payments

APPENDIX B

CANADIAN PER CAPITA MEAT CONSUMPTION, 1960-1969

Item	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Beef	70.0	70.5	71.1	74.3	79.4	83.6	84.1	84.0	86.8	86.4
Pork	52.6	50.3	50.1	50.7	51.8	47.9	46.9	53.8	53.6	51.9
Veal	6.9	6.8	7.1	6.5	7.2	8.3	7.0	7.2	6.4	5.1
Mutton and Lamb	2.9	3.5	3.8	4.0	3.4	2.8	3.4	3.6	4.2	4.0
Variety Meats	4.8	4.5	4.3	4.0	3.9	3.6	3.6	3.9	3.8	4.0
Canned Meats	6.4	4.3	4.2	4.4	4.5	4.2	4.2	4.7	4.3	4.6
Total Red Meat	143.6	139.9	140.6	143.9	150.2	150.4	149.2	157.2	159.1	156.0
Poultry	27.8	31.1	31.0	32.5	34.5	36.0	39.4	40.7	39.7	42.8*
Total Meat	171.4	171.0	171.6	176.4	184.7	186.4	188.6	197.9	198.8	198.8

* DBS estimate

Source: Meat Packers Council of Canada. Islington, Ontario: Meat Packers of Canada, 1969-70. Dominion Bureau of Statistics. Catalogue 21-003, January - March, 1970.

APPENDIX C

GRADE SPECIFICATIONS PRIOR TO JANUARY 1, 1969

Grade	Wt. Range	Min. Length	Max. Shld. Fat	Max. Loin Fat
A	135-150 lbs. 151-170 lbs.	29-29 1/2" 29 1/2-30"	1-3/4" 2"	1 1/4" 1 1/2"
B	125-150 lbs. 151-180 lbs.	28-28-3/4" 29-30"	1-3/4"-2 1/4" 2 1/4-2 1/2" According to weight	1 1/2-1 3/4" 1 3/4-2"
C	125-180 lbs.	None	None May be overfat, lacking in length, type and balance. Also young females with slight mammary development.	None
D	All weights	None	Carcass weighing less than 90 lbs.; thin, underfinished, dark fleshed, rough and soft, oily or having serious physical damage or injury.	
Lights Heavies Extra Heavies	90-124 lbs. 181-195 lbs. Over 195 lbs.		Shall have reasonable finish and quality.	

TABLE OF DIFFERENTIALS FOR THE NEW GRADING SYSTEM

Backfat in.	Predicted yield	POUNDS 90 — 124	125 — 129	130 — 139	140 — 149	150 — 159	160 — 169	170 — 180	181 — 195	196 and over	Ridgling
— 1.9	69.7%	87	105	109	110	112	112	112	91	85	67
2.0 - 2.1	69.0%	87	103	107	109	110	112	112	91	85	67
2.2 - 2.3	68.2%	87	102	105	107	109	110	110	91	85	67
2.4 - 2.5	67.5%	87	100	103	105	107	109	109	91	85	67
2.6 - 2.7	66.7%	87	98	102	103	105	107	107	91	85	67
2.8 - 2.9	66.0%	87	97	100	102	103	105	105	91	85	67
3.0 - 3.1	65.2%	87	95	98	100	[illegible]	103	103	91	85	67
3.2 - 3.3	64.5%	87	92	97	98	[illegible]	102	102	91	85	67
3.4 - 3.5	63.8%	87	88	95	97	98	100	100	91	85	67
3.6 - 3.7	63.0%	87	88	92	95	97	98	98	91	85	67
3.8 - 3.9	62.3%	87	88	88	92	95	97	97	91	85	67
4.0 - 4.1	61.5%	87	88	88	88	92	95	95	87	82	67
4.2 - 4.3	60.8%	87	88	88	88	88	92	92	87	82	67
4.4 - +	60.1%	87	88	88	88	88	88	88	87	82	67

APPENDIX D

ESTIMATED TRANSPORTATION COST BETWEEN PRODUCTION REFERENCE POINTS
AND POTENTIAL ASSEMBLY LOCATIONS

Production reference points	Potential Assembly Locations 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.0	0.90	0.90	0.82	1.13	1.05	1.27	1.35	1.35	1.65	1.35	1.27	1.57	1.57	1.57
2	0.90	0.0	0.82	0.97	0.67	0.82	1.05	1.05	1.13	1.42	1.20	1.42	1.65	1.57	1.65
3	0.90	0.82	0.0	0.60	0.75	0.52	0.90	0.97	0.82	1.05	0.82	1.13	1.50	1.20	1.50
4	0.82	0.97	0.60	0.0	1.05	0.97	1.20	1.27	1.13	0.90	0.82	0.90	1.35	1.27	1.27
5	1.13	0.67	0.75	1.05	0.0	0.60	0.75	0.97	0.97	1.35	1.05	1.27	1.57	1.57	1.57
6	1.05	0.82	0.52	0.97	0.60	0.0	0.70	0.82	0.75	1.57	0.75	1.05	1.50	1.42	1.42
7	1.27	1.05	0.90	1.20	0.75	0.70	0.0	0.75	0.82	1.65	0.97	1.20	1.57	1.57	1.42
8	1.35	1.05	0.97	1.27	0.97	0.82	0.75	0.0	0.75	1.65	0.97	1.27	1.57	1.57	1.42
9	1.35	1.13	0.82	1.13	0.97	0.75	0.82	0.75	0.0	1.42	0.67	1.05	1.35	1.35	1.13
10	1.65	1.42	1.05	0.90	1.35	1.57	1.65	1.65	1.42	0.0	1.20	1.13	0.67	0.75	0.97
11	1.35	1.20	0.82	0.82	1.05	0.75	0.97	0.97	0.67	1.20	0.0	0.90	1.13	1.20	1.13
12	1.27	1.42	1.13	0.90	1.27	1.05	1.20	1.27	1.05	1.13	0.90	0.0	0.90	0.90	0.90
13	1.57	1.65	1.50	1.35	1.57	1.50	1.57	1.57	1.35	0.67	1.13	0.90	0.0	0.67	0.97
14	1.57	1.57	1.20	1.27	1.57	1.42	1.57	1.57	1.35	0.75	1.20	0.90	0.67	0.0	0.52
15	1.57	1.65	1.50	1.27	1.57	1.42	1.42	1.42	1.13	0.97	1.13	0.90	0.97	0.52	0.0
16	1.57	1.35	1.05	0.97	1.20	1.05	1.05	0.97	0.60	1.35	0.60	0.82	1.13	1.13	0.90
17	1.42	1.57	1.27	1.05	1.42	1.20	1.20	1.20	0.90	1.20	0.90	0.45	0.97	0.97	0.60
18	1.65	1.72	1.65	1.57	1.65	1.65	1.65	1.65	1.57	0.90	1.50	1.20	0.82	0.82	1.05
19	1.50	1.57	1.27	1.05	1.72	1.65	1.72	1.72	1.72	0.60	1.57	1.27	0.97	1.05	1.20
20	1.65	1.65	1.42	1.27	1.88	1.80	1.88	1.88	1.72	0.97	1.65	1.50	1.20	1.27	1.42
21	1.95	1.57	1.57	1.42	1.95	1.80	1.95	1.95	1.80	1.05	1.65	1.57	1.27	1.35	1.50
22	2.25	1.57	1.57	1.88	2.25	1.95	2.10	2.10	1.88	1.27	1.80	1.65	1.50	1.42	1.57
23	1.72	1.80	1.65	1.57	1.72	1.65	1.65	1.65	1.50	1.42	1.50	1.27	1.27	0.97	0.97
24	1.72	1.80	1.65	1.57	1.72	1.65	1.65	1.65	1.57	1.27	1.50	1.27	1.13	1.05	0.90
25	1.65	1.72	1.65	1.57	1.65	1.57	1.57	1.57	1.42	1.20	1.42	1.20	1.05	0.97	0.82
26	1.65	1.65	1.57	1.57	1.65	1.57	1.57	1.35	1.27	1.35	1.13	1.13	0.75	0.82	1.13
27	1.65	1.65	1.57	1.42	1.65	1.57	1.57	1.57	1.27	1.13	1.27	1.05	1.05	0.60	0.67
28	1.95	2.10	1.88	1.88	1.95	1.80	1.65	1.80	1.72	1.20	1.65	1.65	1.42	1.50	1.35
29	2.25	2.40	2.10	1.88	2.25	1.95	2.10	1.95	1.80	1.27	1.95	1.65	1.50	1.57	1.57
30	1.80	1.95	1.72	1.65	1.80	1.72	1.72	1.72	1.57	1.27	1.57	1.50	1.20	1.05	1.20

Note: Please refer to page 54 to correspond the numbers to the respective locations.

APPENDIX D (Continued)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	1.57	1.42	1.65	1.50	1.65	1.35	2.25	1.72	1.72	1.65	1.65	1.65	1.95	2.25	1.80
2	1.35	1.57	1.72	1.57	1.65	1.57	1.57	1.80	1.80	1.72	1.65	1.65	2.10	2.40	1.95
3	1.05	1.27	1.65	1.27	1.42	1.57	1.57	1.65	1.65	1.65	1.57	1.57	1.88	2.10	1.72
4	0.97	1.05	1.57	1.05	1.27	1.42	1.88	1.57	1.57	1.57	1.57	1.42	1.88	1.88	1.65
5	1.20	1.42	1.65	1.72	1.88	1.95	2.25	1.72	1.72	1.65	1.65	1.65	1.95	2.25	1.80
6	1.05	1.20	1.65	1.65	1.80	1.80	1.95	1.65	1.65	1.57	1.57	1.57	1.80	1.95	1.72
7	1.05	1.20	1.65	1.72	1.88	1.95	2.10	1.65	1.65	1.57	1.57	1.57	1.65	2.10	1.72
8	0.97	1.20	1.65	1.72	1.88	1.95	2.10	1.65	1.65	1.57	1.35	1.57	1.80	1.95	1.72
9	0.60	0.90	1.57	1.72	1.72	1.80	1.88	1.50	1.57	1.42	1.27	1.27	1.72	1.80	1.57
10	1.35	1.20	0.90	0.60	0.97	1.05	1.27	1.42	1.27	1.20	1.35	1.13	1.20	1.27	1.27
11	0.60	0.90	1.50	1.57	1.65	1.65	1.80	1.50	1.50	1.42	1.13	1.27	1.65	1.95	1.57
12	0.82	0.45	1.20	1.27	1.50	1.57	1.35	1.27	1.27	1.20	1.13	1.05	1.65	1.65	1.50
13	1.13	0.97	0.82	0.97	1.20	1.27	1.50	1.27	1.13	1.05	0.75	1.05	1.42	1.50	1.20
14	1.13	0.97	0.82	1.05	1.27	1.35	1.42	0.97	1.05	0.97	0.82	0.60	1.50	1.57	1.05
15	0.90	0.60	1.05	1.20	1.42	1.50	1.57	0.97	0.90	0.82	1.13	0.67	1.35	1.57	1.20
16	0.0	0.60	1.50	1.57	1.65	1.65	1.88	1.35	1.35	1.27	0.97	1.05	1.57	1.65	1.57
17	0.60	0.0	1.27	1.42	1.57	1.65	1.65	1.13	1.13	1.05	0.82	0.82	1.57	1.65	1.35
18	1.50	1.27	0.0	0.52	0.90	0.97	1.27	0.97	0.82	0.67	1.05	0.90	1.13	1.27	0.82
19	1.57	1.42	0.52	0.0	0.67	0.82	0.97	1.20	1.05	0.97	1.27	1.05	0.97	1.05	1.05
20	1.65	1.57	0.90	0.67	0.0	0.67	0.82	1.42	0.90	1.05	1.35	1.20	0.60	0.82	0.67
21	1.65	1.65	0.97	0.82	0.67	0.0	0.45	1.50	1.35	1.27	1.42	1.27	0.97	1.13	0.97
22	1.88	1.65	1.27	0.97	0.82	0.45	0.0	1.57	1.27	1.35	0.52	1.35	0.82	0.97	1.05
23	1.35	1.13	0.97	1.20	1.42	1.50	1.57	0.0	0.82	0.60	0.52	0.67	1.27	1.35	1.05
24	1.35	1.13	0.82	1.05	0.90	1.35	1.27	0.82	0.0	0.38	0.38	0.67	0.97	1.35	0.60
25	1.27	1.05	0.67	0.97	1.05	1.27	1.35	0.60	0.38	0.0	0.38	0.52	1.05	1.42	0.82
26	0.97	0.82	1.05	1.27	1.35	1.42	0.52	0.52	0.38	0.38	0.0	0.38	1.13	1.50	0.90
27	1.05	0.82	0.90	1.05	1.20	1.27	1.35	0.67	0.67	0.52	0.38	0.0	1.20	1.57	0.97
28	1.57	1.57	1.13	0.97	0.60	0.97	0.82	1.27	0.97	1.05	1.13	1.20	0.0	0.75	0.75
29	1.65	1.65	1.27	1.05	0.82	1.13	0.97	1.35	1.35	1.42	1.50	1.57	0.75	0.0	0.97
30	1.57	1.35	0.82	1.05	0.67	0.97	1.05	1.05	0.60	0.82	0.90	0.97	0.75	0.97	0.0

APPENDIX D (Continued)

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1	2.40	2.55	2.25	2.10	1.95	1.72	1.88	2.10	2.25	2.55	2.55	2.55	2.25	2.25	2.40
2	2.55	2.70	2.40	2.25	2.10	1.88	1.95	2.25	2.40	2.55	2.70	2.55	2.40	2.40	2.40
3	2.40	2.40	1.95	1.95	1.88	1.65	1.80	1.95	2.10	2.40	2.55	2.40	1.95	2.10	2.10
4	2.10	2.40	1.88	1.80	1.72	1.65	1.72	1.80	1.95	2.25	2.40	2.25	1.88	1.95	1.95
5	2.40	2.55	2.25	2.10	1.95	1.72	1.88	2.10	2.25	2.40	2.55	2.55	2.25	2.25	2.40
6	2.10	2.40	1.95	1.88	1.88	1.65	1.80	1.88	2.10	2.25	2.40	2.40	1.95	2.10	2.10
7	2.25	2.40	1.95	1.88	1.88	1.65	1.80	1.95	2.10	2.40	2.55	2.40	1.95	2.10	2.10
8	2.25	2.40	1.95	1.88	1.80	1.65	1.72	1.88	1.95	2.40	2.40	2.40	1.95	2.10	2.10
9	1.95	2.10	1.80	1.72	1.65	1.57	1.65	1.72	1.80	1.95	2.25	2.10	1.80	1.80	1.80
10	1.35	1.57	1.27	1.65	1.57	1.35	1.57	1.65	1.65	1.80	1.95	1.88	1.88	1.65	1.72
11	1.88	1.95	1.95	1.72	1.65	1.57	1.65	1.72	1.80	1.95	2.25	2.10	1.80	1.80	1.65
12	1.65	1.80	1.65	1.65	1.57	1.35	1.57	1.65	1.65	1.80	1.95	1.88	1.65	1.65	1.72
13	1.57	1.65	1.50	1.57	1.57	1.27	1.50	1.57	1.65	1.57	1.65	1.80	1.65	1.65	1.65
14	1.57	1.65	1.57	1.50	1.35	1.05	1.27	1.50	1.57	1.65	1.80	1.65	1.57	1.57	1.57
15	1.65	1.65	1.57	1.57	1.57	1.13	1.50	1.57	1.65	1.80	1.88	1.80	1.65	1.65	1.65
16	1.80	1.95	1.65	1.65	1.57	1.42	1.57	1.65	1.72	1.88	2.10	1.88	1.65	1.72	1.72
17	1.72	1.57	1.57	1.57	1.57	1.20	1.42	1.50	1.65	1.72	1.88	1.80	1.57	1.65	1.65
18	1.35	1.57	1.20	1.42	1.27	0.97	1.20	1.42	1.57	1.88	1.72	1.65	1.50	1.57	1.57
19	1.13	1.35	1.05	1.57	1.42	1.13	1.35	1.57	1.57	1.72	1.80	2.25	1.57	1.57	1.65
20	0.97	1.27	0.75	1.27	1.13	0.82	1.05	1.27	1.42	1.80	1.65	1.57	1.35	1.42	1.50
21	0.82	0.97	1.05	1.50	1.42	1.13	1.27	1.50	1.57	1.65	1.80	1.72	1.57	1.57	1.57
22	0.52	0.90	0.90	1.05	1.27	1.20	1.13	1.35	1.50	1.05	1.13	1.65	1.42	1.57	1.57
23	1.57	1.65	1.50	1.35	1.20	0.97	1.13	1.35	1.50	1.65	1.65	1.65	1.42	1.50	1.57
24	1.42	1.57	1.27	1.05	0.90	0.38	0.82	1.05	1.20	1.50	1.57	1.57	1.13	1.20	1.27
25	1.50	1.57	1.42	1.13	1.05	0.60	0.90	1.13	1.27	1.57	1.65	1.57	1.20	1.35	1.35
26	1.57	1.65	1.20	1.65	1.13	0.75	0.97	0.97	1.35	1.57	1.65	1.57	1.27	1.42	1.42
27	1.65	1.65	1.57	1.27	1.20	0.82	1.13	1.35	1.42	1.57	1.65	1.65	1.42	1.50	1.50
28	1.05	1.20	0.45	0.75	0.90	0.82	0.82	1.05	1.20	1.50	1.57	1.57	1.13	1.20	1.27
29	0.82	1.05	0.52	0.60	0.90	1.13	0.97	1.20	1.35	1.57	1.65	1.57	1.27	1.35	1.42
30	1.20	1.35	1.05	1.05	0.97	0.45	0.82	1.05	1.20	1.27	1.50	1.57	1.13	1.27	1.27

APPENDIX D (Continued)

	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	2.25	2.10	2.40	2.70	2.85	3.00	3.00	2.85	3.15	3.00	3.00	3.15	3.00	3.15	3.45
2	2.40	2.40	2.55	2.85	3.00	3.00	3.15	3.00	3.30	3.15	3.15	3.30	3.15	3.30	3.45
3	2.10	1.95	2.25	2.70	2.85	2.85	3.00	2.85	3.15	3.00	3.00	3.00	2.85	3.15	3.30
4	1.95	1.88	2.10	2.55	2.70	2.70	2.85	2.70	3.00	2.85	2.85	3.00	2.85	3.00	3.30
5	2.25	2.10	2.40	2.70	2.85	3.00	3.00	2.85	3.15	3.00	3.00	3.15	3.00	3.15	3.45
6	1.95	1.95	2.25	2.55	2.70	2.85	2.85	2.70	3.00	3.00	2.85	3.00	2.85	3.15	3.30
7	2.10	1.95	2.25	2.70	2.85	2.85	2.85	2.70	3.00	3.00	3.00	3.00	2.85	3.00	3.30
8	1.95	1.88	2.25	2.55	2.70	2.85	2.85	2.70	3.00	2.85	2.85	3.00	2.85	3.15	3.30
9	2.25	1.72	1.95	2.40	2.55	2.70	2.70	2.55	2.85	2.70	2.70	2.85	2.70	2.85	3.15
10	1.65	1.65	1.80	2.25	2.40	2.55	2.55	2.40	2.70	2.55	2.55	2.70	2.55	2.70	3.00
11	1.80	1.72	1.95	2.40	2.55	2.70	2.70	2.55	2.85	2.70	2.70	2.85	2.70	2.85	3.15
12	1.95	1.65	1.80	2.25	2.40	2.55	2.55	2.40	2.70	2.55	2.55	2.70	2.55	2.70	3.00
13	1.65	1.57	1.72	2.10	2.40	2.40	2.55	2.40	2.70	2.55	2.55	2.70	2.55	2.70	3.00
14	1.57	1.57	1.65	1.88	2.25	2.25	2.40	2.10	2.55	2.40	2.40	2.55	2.40	2.55	2.85
15	1.65	1.57	1.72	2.10	2.40	2.40	2.55	2.40	2.70	2.55	2.55	2.70	2.55	2.70	3.00
16	1.65	1.65	1.80	2.25	2.40	2.55	2.55	2.40	2.70	2.70	2.55	2.70	2.55	2.85	3.00
17	1.65	1.57	1.72	2.10	2.40	2.40	2.55	2.40	2.70	2.55	2.55	2.55	2.40	2.70	3.00
18	1.50	1.42	1.57	1.88	2.10	2.10	2.25	1.95	2.55	2.40	2.40	2.40	2.25	2.55	2.70
19	2.25	1.57	1.65	1.95	2.25	2.40	2.40	2.25	2.55	2.40	2.40	2.55	2.40	2.55	2.85
20	1.42	1.27	1.57	1.72	1.95	1.95	2.10	1.88	2.40	2.25	2.25	2.40	2.10	2.40	2.70
21	1.57	1.57	1.65	1.95	2.25	2.25	2.40	2.10	2.55	2.40	2.40	2.55	2.40	2.55	2.85
22	1.57	1.42	1.57	1.88	2.10	2.10	2.25	1.95	2.55	2.40	2.40	2.40	2.25	2.55	2.70
23	1.50	1.42	1.57	1.80	1.95	2.10	2.25	1.95	2.40	2.40	2.25	2.40	2.25	2.55	2.70
24	1.20	1.13	1.42	1.65	1.80	1.88	1.95	1.80	2.25	1.95	1.95	2.10	1.88	2.25	2.55
25	1.27	1.20	1.50	1.72	1.88	1.88	1.95	1.80	2.40	2.10	2.10	2.25	1.95	2.40	2.55
26	1.35	1.27	1.57	1.72	1.88	1.95	2.10	1.88	2.40	2.10	2.10	2.40	2.10	2.40	2.70
27	1.42	1.35	1.57	1.80	1.95	2.10	2.25	1.95	2.40	2.25	2.25	2.40	2.10	2.40	2.70
28	1.20	1.13	1.42	1.65	1.80	1.88	1.95	1.80	2.25	1.95	1.95	2.10	1.88	2.25	2.55
29	1.35	1.27	1.57	1.72	1.88	1.95	2.10	1.88	2.40	2.10	2.10	2.40	2.10	2.40	2.70
30	1.20	1.13	1.42	1.65	1.80	1.88	1.95	1.80	2.25	1.95	1.95	2.25	1.88	2.25	2.55

APPENDIX D (Continued)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
31	2.40	2.55	2.40	2.10	2.40	2.10	2.25	2.25	1.95	1.35	1.83	1.65	1.57	1.57	1.65
32	2.55	2.70	2.40	2.40	2.55	2.40	2.40	2.40	2.10	1.57	1.95	1.80	1.65	1.65	1.65
33	2.25	2.40	1.95	1.88	2.25	1.95	1.95	1.95	1.80	1.27	1.95	1.65	1.50	1.57	1.57
34	2.10	2.25	1.95	1.80	2.10	1.83	1.88	1.88	1.72	1.65	1.72	1.65	1.57	1.50	1.57
35	1.95	2.10	1.88	1.72	1.95	1.88	1.83	1.80	1.65	1.57	1.65	1.57	1.57	1.35	1.57
36	1.72	1.88	1.65	1.65	1.72	1.65	1.65	1.65	1.57	1.35	1.57	1.35	1.27	1.05	1.13
37	1.88	1.95	1.80	1.72	1.88	1.80	1.80	1.72	1.65	1.57	1.65	1.57	1.50	1.27	1.50
38	2.10	2.25	1.95	1.80	2.10	1.88	1.95	1.88	1.72	1.65	1.72	1.65	1.57	1.50	1.57
39	2.25	2.40	2.10	1.95	2.25	2.10	2.10	1.95	1.80	1.65	1.80	1.65	1.65	1.57	1.65
40	2.55	2.55	2.40	2.25	2.40	2.25	2.40	2.40	1.95	1.80	1.95	1.80	1.57	1.65	1.80
41	2.55	2.70	2.55	2.40	2.55	2.40	2.55	2.40	2.25	1.95	2.25	1.95	1.65	1.80	1.88
42	2.55	2.55	2.40	2.25	2.55	2.40	2.40	2.40	2.10	1.88	2.10	1.88	1.80	1.65	1.80
43	2.25	2.40	1.95	1.80	2.25	1.95	1.95	1.95	1.80	1.88	1.80	1.65	1.65	1.57	1.65
44	2.25	2.40	2.10	1.95	2.25	2.10	2.10	2.10	1.80	1.65	1.80	1.65	1.65	1.57	1.65
45	2.40	2.40	2.10	1.95	2.40	2.10	2.10	2.10	1.83	1.72	1.83	1.72	1.65	1.57	1.65
46	2.25	2.40	2.10	1.95	2.25	1.95	2.10	1.95	2.25	1.65	1.80	1.95	1.65	1.57	1.65
47	2.10	2.40	1.95	1.88	2.10	1.95	1.95	1.83	1.72	1.65	1.72	1.65	1.57	1.57	1.57
48	2.40	2.55	2.25	2.10	2.40	2.25	2.25	2.25	1.95	1.80	1.95	1.80	1.72	1.65	1.72
49	2.70	2.85	2.70	2.55	2.70	2.55	2.70	2.55	2.40	2.25	2.40	2.25	2.10	1.88	2.10
50	2.85	3.00	2.85	2.70	2.85	2.70	2.85	2.70	2.55	2.40	2.55	2.40	2.40	2.25	2.40
51	3.00	3.00	2.85	2.70	3.00	2.85	2.85	2.85	2.70	2.55	2.70	2.55	2.40	2.25	2.40
52	3.00	3.15	3.00	2.85	3.00	2.85	2.85	2.85	2.70	2.55	2.70	2.55	2.55	2.40	2.55
53	2.85	3.00	2.85	2.70	2.85	2.70	2.70	2.70	2.55	2.40	2.55	2.40	2.40	2.10	2.40
54	3.15	3.30	3.15	3.00	3.15	3.00	3.00	3.00	2.85	2.70	2.85	2.70	2.70	2.55	2.70
55	3.00	3.15	3.00	2.85	3.00	3.00	3.00	2.85	2.70	2.55	2.70	2.55	2.55	2.40	2.55
56	3.00	3.15	3.00	2.85	3.00	2.85	3.00	2.85	2.70	2.55	2.70	2.55	2.55	2.40	2.55
57	3.15	3.30	3.00	3.00	3.15	3.00	3.00	3.00	2.85	2.70	2.85	2.70	2.70	2.55	2.70
58	3.00	3.15	2.85	2.85	3.00	2.85	2.85	2.85	2.70	2.55	2.70	2.55	2.55	2.40	2.55
59	3.15	3.30	3.15	3.00	3.15	3.15	3.00	3.15	2.85	2.70	2.85	2.70	2.70	2.55	2.70
60	3.45	3.45	3.30	3.30	3.45	3.30	3.30	3.30	3.15	3.00	3.15	3.00	3.00	2.85	3.00

APPENDIX D (Continued)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
31	1.80	1.72	1.35	1.13	0.97	0.82	0.52	1.57	1.42	1.50	1.57	1.65	1.05	0.82	1.20
32	1.95	1.57	1.57	1.35	1.27	0.97	0.90	1.65	1.57	1.57	1.65	1.65	1.20	1.05	1.35
33	1.65	1.57	1.20	1.05	0.75	1.05	0.90	1.50	1.27	1.42	1.20	1.57	0.45	0.52	1.05
34	1.65	1.57	1.42	1.57	1.27	1.50	1.05	1.35	1.05	1.13	1.65	1.27	0.75	0.60	1.05
35	1.57	1.57	1.27	1.42	1.13	1.42	1.27	1.20	0.90	1.05	1.13	1.20	0.90	0.90	0.97
36	1.42	1.20	0.97	1.13	0.82	1.13	1.20	0.97	0.38	0.60	0.75	0.82	0.32	1.13	0.45
37	1.57	1.42	1.20	1.35	1.05	1.27	1.13	1.13	0.32	0.90	0.97	1.13	0.82	0.97	0.82
38	1.65	1.50	1.42	1.57	1.27	1.50	1.35	1.35	1.05	1.13	0.97	1.35	1.05	1.20	1.05
39	1.72	1.65	1.57	1.57	1.42	1.57	1.50	1.50	1.20	1.27	1.35	1.42	1.20	1.35	1.20
40	1.88	1.72	1.88	1.72	1.80	1.65	1.65	1.65	1.50	1.57	1.57	1.57	1.50	1.57	1.27
41	2.10	1.88	1.72	1.80	1.65	1.80	1.13	1.65	1.57	1.65	1.65	1.65	1.57	1.65	1.50
42	1.88	1.80	1.65	2.25	1.57	1.72	1.65	1.65	1.57	1.57	1.57	1.65	1.57	1.57	1.57
43	1.65	1.57	1.50	1.57	1.35	1.57	1.42	1.42	1.13	1.20	1.27	1.42	1.13	1.27	1.13
44	1.72	1.65	1.57	1.57	1.42	1.57	1.57	1.50	1.20	1.35	1.42	1.50	1.20	1.35	1.27
45	1.72	1.65	1.57	1.65	1.50	1.57	1.57	1.57	1.27	1.35	1.42	1.50	1.27	1.42	1.27
46	1.65	1.65	1.50	2.25	1.42	1.57	1.57	1.50	1.20	1.27	1.35	1.42	1.20	1.35	1.20
47	1.65	1.57	1.42	1.57	1.27	1.57	1.42	1.42	1.13	1.20	1.27	1.35	1.13	1.27	1.13
48	1.80	1.72	1.57	1.65	1.57	1.65	1.57	1.57	1.42	1.50	1.57	1.57	1.42	1.57	1.42
49	2.25	2.10	1.88	1.95	1.72	1.95	1.88	1.80	1.65	1.72	1.72	1.80	1.65	1.72	1.65
50	2.40	2.40	2.10	2.25	1.95	2.25	2.10	1.95	1.80	1.88	1.88	1.95	1.80	1.88	1.80
51	2.55	2.40	2.10	2.40	1.95	2.25	2.10	2.10	1.88	1.88	1.95	2.10	1.88	1.95	1.88
52	2.55	2.55	2.25	2.40	2.10	2.40	2.25	2.25	1.95	1.95	2.10	2.25	1.95	2.10	1.95
53	2.40	2.40	1.95	2.25	1.88	2.10	1.95	1.95	1.80	1.80	1.88	1.95	1.80	1.88	1.80
54	2.70	2.70	2.55	2.55	2.40	2.55	2.55	2.40	2.25	2.40	2.40	2.40	2.25	2.40	2.25
55	2.70	2.55	2.40	2.40	2.25	2.40	2.40	2.40	1.95	2.10	2.10	2.25	1.95	2.10	1.95
56	2.55	2.55	2.40	2.40	2.25	2.40	2.40	2.25	1.95	2.10	2.10	2.25	1.95	2.10	1.95
57	2.70	2.55	2.40	2.55	2.40	2.55	2.40	2.40	2.10	2.25	2.40	2.40	2.10	2.40	2.25
58	2.55	2.40	2.25	2.40	2.10	2.40	2.25	2.25	1.88	1.95	2.10	2.10	1.80	2.10	1.88
59	2.85	2.70	2.55	2.55	2.40	2.55	2.55	2.55	2.25	2.40	2.40	2.40	2.25	2.40	2.25
60	3.00	3.00	2.70	2.85	2.70	2.85	2.70	2.70	2.55	2.55	2.70	2.70	2.55	2.70	2.55

APPENDIX D (Continued)

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
31	0.0	0.60	0.75	0.82	1.20	1.35	1.13	1.35	1.57	0.82	0.82	1.27	1.27	1.50	1.50
32	0.60	0.0	0.97	1.05	1.42	1.50	1.27	1.50	1.20	1.05	1.05	1.35	1.57	2.10	1.57
33	0.75	0.97	0.0	0.60	0.90	1.05	0.82	1.05	1.05	0.82	1.05	0.97	0.97	1.20	1.27
34	0.82	1.05	0.60	0.0	0.52	0.97	0.60	0.97	0.60	0.90	1.13	0.97	0.60	1.13	1.20
35	1.20	1.42	0.90	0.52	0.0	0.82	0.38	0.82	0.97	1.05	1.20	1.20	0.67	0.97	0.82
36	1.35	1.50	1.05	0.97	0.82	0.0	0.60	0.97	1.13	1.42	1.57	1.42	1.05	1.13	1.20
37	1.13	1.27	0.82	0.60	0.38	0.60	0.0	0.60	0.90	1.20	1.42	1.20	0.75	0.90	0.97
38	1.35	1.50	1.05	0.97	0.82	0.97	0.60	0.0	1.13	1.42	1.57	1.42	1.05	0.97	1.20
39	1.57	1.20	1.05	0.60	0.97	1.13	0.90	1.13	0.0	0.75	0.90	0.82	0.60	0.97	0.90
40	0.82	1.05	0.82	0.90	1.05	1.42	1.20	1.42	0.75	0.0	0.60	0.90	0.90	1.27	1.20
41	0.82	1.05	1.05	1.13	1.20	1.57	1.42	1.57	0.90	0.60	0.0	0.82	0.97	1.35	1.20
42	1.27	1.35	0.97	0.97	1.20	1.42	1.20	1.42	0.82	0.90	0.82	0.0	0.82	1.20	0.82
43	1.27	1.57	0.97	0.60	0.67	1.05	0.75	1.05	0.60	0.90	0.97	0.82	0.0	0.82	0.67
44	1.50	2.10	1.20	1.13	0.97	1.13	0.90	0.97	0.97	1.27	1.35	1.20	0.82	0.0	0.90
45	1.50	1.57	1.27	1.20	0.82	1.20	0.97	1.20	0.90	1.20	1.20	0.82	0.67	0.90	0.0
46	1.50	1.57	1.20	1.13	0.90	1.13	0.90	0.90	1.20	1.50	1.57	1.42	1.05	0.60	1.05
47	1.35	1.57	1.05	0.97	0.52	0.97	0.75	0.97	0.82	1.13	1.27	1.05	0.60	0.45	0.67
48	1.57	1.65	1.35	1.27	1.05	1.27	1.05	1.13	1.35	1.57	1.65	1.57	1.27	0.90	1.50
49	1.80	1.88	1.65	1.65	1.57	1.65	1.57	1.57	1.65	1.57	1.65	1.65	1.35	1.42	1.57
50	1.80	2.25	1.80	1.72	1.65	1.72	1.65	1.65	1.65	1.80	1.88	1.65	1.35	1.57	1.57
51	2.10	2.25	1.80	1.80	1.65	1.80	1.65	1.72	1.88	2.10	2.25	1.80	1.80	1.65	1.65
52	2.25	2.40	1.95	1.88	1.72	1.88	1.72	1.80	1.95	2.25	2.40	1.95	1.88	1.65	1.72
53	1.95	2.10	1.80	1.72	1.65	1.72	1.65	1.65	1.57	1.65	1.72	1.57	1.57	1.57	1.27
54	2.40	2.55	2.25	2.10	1.88	2.10	1.88	1.95	1.95	2.25	2.40	1.88	1.88	1.80	1.72
55	2.25	2.40	1.95	1.88	1.72	1.88	1.80	1.80	1.88	2.10	2.25	1.80	1.80	1.65	1.65
56	2.25	2.40	1.95	1.88	1.72	1.88	1.72	1.80	1.80	1.95	2.10	1.80	1.72	1.65	1.65
57	2.40	2.55	2.10	2.10	1.88	2.10	1.88	1.88	1.95	2.40	2.40	1.95	1.88	1.72	1.72
58	2.10	2.55	1.88	1.88	1.72	1.88	1.72	1.72	1.72	1.95	1.95	1.72	1.65	1.72	1.57
59	2.40	2.55	2.25	2.10	1.95	2.10	1.95	1.95	1.95	2.40	2.40	1.95	1.80	1.80	1.72
60	2.70	2.85	2.55	2.55	2.40	2.55	2.40	2.40	2.40	2.25	2.70	2.40	2.40	2.25	2.10

APPENDIX D (Continued)

	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
31	1.50	1.35	1.57	1.90	1.80	2.10	2.25	1.95	2.40	2.25	2.25	2.40	2.10	2.40	2.70
32	1.57	1.57	1.65	1.88	2.25	2.25	2.40	2.10	2.55	2.40	2.40	2.55	2.55	2.55	2.85
33	1.20	1.05	1.35	1.65	1.80	1.80	1.95	1.80	2.25	1.95	1.95	2.10	1.88	2.25	2.55
34	1.13	0.97	1.27	1.65	1.72	1.80	1.88	1.72	2.10	1.88	1.88	2.10	1.88	2.10	2.55
35	0.90	0.52	1.05	1.57	1.65	1.65	1.72	1.65	1.88	1.72	1.72	1.88	1.72	1.95	2.40
36	1.13	0.97	1.27	1.65	1.72	1.80	1.88	1.72	2.10	1.88	1.88	2.10	1.88	2.10	2.55
37	0.90	0.75	1.05	1.57	1.65	1.65	1.72	1.65	1.88	1.80	1.72	1.88	1.72	1.95	2.40
38	0.90	0.97	1.13	1.57	1.65	1.72	1.80	1.65	1.95	1.80	1.80	1.88	1.72	1.95	2.40
39	1.20	0.32	1.35	1.65	1.65	1.88	1.95	1.57	1.95	1.88	1.80	1.95	1.72	1.95	2.40
40	1.50	1.13	1.57	1.57	1.80	2.10	2.25	1.65	2.25	2.10	1.95	2.40	1.95	2.40	2.25
41	1.57	1.27	1.65	1.88	1.88	2.25	2.40	1.72	2.40	2.25	2.10	2.40	1.95	2.40	2.70
42	1.42	1.05	1.57	1.65	1.65	1.80	1.95	1.57	1.88	1.80	1.80	1.95	1.72	1.95	2.40
43	1.05	0.60	1.27	1.65	1.65	1.80	1.88	1.57	1.88	1.80	1.72	1.80	1.65	1.88	2.40
44	0.60	0.45	0.90	1.42	1.57	1.65	1.65	1.57	1.80	1.65	1.65	1.72	1.72	1.80	2.25
45	1.05	0.67	1.50	1.57	1.57	1.65	1.72	1.27	1.72	1.65	1.65	1.72	1.57	1.72	2.10
46	0.0	0.82	0.60	1.27	1.50	1.57	1.57	1.50	1.65	1.65	1.57	1.65	1.57	1.72	1.95
47	0.82	0.0	1.05	1.57	1.65	1.65	1.72	1.65	1.88	1.72	1.72	1.88	1.80	1.88	2.40
48	0.60	1.05	0.0	1.05	1.27	1.35	1.50	1.27	1.65	1.57	1.57	1.57	1.50	1.65	1.80
49	1.27	1.57	1.05	0.0	0.67	0.82	0.97	0.67	1.27	1.05	1.05	1.20	0.97	1.27	1.57
50	1.50	1.65	1.27	0.67	0.0	1.05	1.20	0.67	1.05	0.82	0.82	0.97	0.52	1.05	1.50
51	1.57	1.65	1.35	0.82	1.05	0.0	0.45	1.13	1.35	0.67	1.05	0.82	0.90	0.97	1.57
52	1.57	1.72	1.50	0.97	1.20	0.45	0.0	1.20	1.42	0.90	1.20	0.97	0.97	1.13	1.65
53	1.50	1.65	1.27	0.67	0.67	1.13	1.20	0.0	1.27	1.13	1.05	1.20	0.97	1.35	1.50
54	1.65	1.88	1.65	1.27	1.05	1.35	1.42	1.27	0.0	1.13	0.75	0.97	1.20	1.05	0.97
55	1.65	1.72	1.57	1.05	0.82	0.67	0.90	1.13	1.13	0.0	0.90	0.60	0.60	0.75	1.57
56	1.57	1.72	1.57	1.05	0.82	1.05	1.20	1.05	0.75	0.90	0.0	0.52	0.97	0.75	1.20
57	1.65	1.88	1.57	1.20	0.97	0.82	0.97	1.20	0.97	0.60	0.52	0.0	0.75	0.38	1.42
58	1.57	1.80	1.50	0.97	0.52	0.90	0.97	0.97	1.20	0.60	0.97	0.75	0.0	0.90	1.27
59	1.72	1.88	1.65	1.27	1.05	0.97	1.13	1.35	1.05	0.75	0.75	0.38	0.90	0.0	1.50
60	1.95	2.40	1.80	1.57	1.50	1.57	1.65	1.50	0.97	1.57	1.20	1.42	1.27	1.50	0.0

APPENDIX E

VARIABLE COSTS / HOG (cents)

Capacity Range	Utilities	Supplies	Advert.	Clerical and Professional	Repairs	Ins.	Interest, Bank Chgs.	Wages	TOTAL	Size
1.	3	2	1	2	2	.5	1.5	21	33.0	I
2.	2.5	2	1	2	1.78	.25	1.27	11	21.8	I
3.	2.5	2	1	2	1.6	.15	.96	6.6	16.8	I
4.	1.8	1.8	.75	1.8	1.48	.36	.86	7.4	16.3	II
5.	1.6	1.8	.75	1.8	1.2	.20	.55	6.2	14.2	II
6.	1.5	1.8	.75	1.5	1.0	.13	.33	6.6	13.7	III
7.	1.0	1.6	.65	1.5	.86	.08	.14	5.3	11.1	III

FIXED COSTS

Size	Fixed Assets	Depreciation	Taxes	Int. On Investment	TOTAL
I	$5,000 buildings and corrals $2,000 scales and equipment	@ 5% = $250/yr @ 10% = $200/yr.	$80	$420	$950
II	$10,000 " " " $2,000 " " "	@ 5% = $500/yr @ 10% = $200/yr	$200	$720	$1620
III	$13,000 " " " $2,000 " " "	@ 5% = $650/yr. @ 10% = $200/yr.	$350	$900	$2100

APPENDIX F

SENSITIVITY ANALYSIS ON ASSEMBLY OPERATING COSTS

Change in Costs	No. of Locations	TFATC	TAOC	TASTC	TCC
-30% in	52	$ 8,440	$198,100	$1,111,832	$1,318,372
fixed	53	6,529	199,395	1,112,054	1,317,978
and	54	5,027	200,352	1,112,429	1,317,808**
variable	55	3,724	201,311	1,112,906	1,317,941
-20% in	50	13,349	222,782	1,109,875	1,346,006
fixed	51	10,399	224,470	1,110,224	1,345,093*
and	52	8,440	225,845	1,111,832	1,345,117
variable					
-10% in					
fixed	50	13,349	250,654	1,109,875	1,373,878
and	51	10,399	252,552	1,110,224	1,373,175*
variable	52	8,440	254,163	1,111,832	1,374,435
-10%	50	13,349	272,044	1,109,875	1,395,267
in	51	10,399	274,056	1,110,224	1,394,679*
fixed	52	8,440	275,752	1,111,832	1,396,024
Normal assembly costs	51	10,397	281,247	1,110,224	1,401,868
+10%	50	13,349	286,236	1,109,875	1,409,459
in	51	10,399	288,438	1,110,224	1,409,061*
fixed	52	8,440	290,324	1,111,832	1,410,596
+10% in	50	13,349	310,711	1,109,875	1,433,935
fixed and	51	10,399	313,028	1,110,224	1,433,651*
variable	52	8,440	315,005	1,111,832	1,435,277
+20% in	50	13,349	334,431	1,109,875	1,457,655
fixed and	51	10,399	336,972	1,110,224	1,457,595*
variable	52	8,440	339,122	1,111,832	1,459,394
+30% in	48	19,941	357,635	1,108,677	1,486,253
fixed and	49	16,641	360,748	1,108,677	1,486,066**
variable	50	13,349	362,849	1,109,875	1,486,073
	51	10,399	365,590	1,111,832	1,487,821

Note: Totals may not be exact because of round-off error.

*Indicates the least-cost solution.

**Indicates a change in the least-cost solution.

APPENDIX G

ASSEMBLY LOCATIONS IN THE ORDER AS CHOSEN
BY THE LONG-RUN SPATIAL MODEL

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1. Wetaskiwin
2. Calgary
3. Edmonton
4. Lethbridge
5. Red Deer
6. Vegreville
7. Grande Prairie
8. Barrhead
9. St. Paul
10. Camrose
11. Lacombe
12. Vermilion
13. Killam
14. Westlock
15. Three Hills
16. Brooks
17. Stettler
18. Bonnyville
19. Sangudo
20. Lamont
21. Grimshaw
22. Innisfail
23. Two Hills
24. Athabasca
25. Ponoka
26. Didsbury
27. Claresholm
28. Thorsby
29. Valleyview
30. Smoky Lake
31. Vauxhall
32. Morinville
33. Wainwright
34. Holden
35. Lloydminster
36. Beaverlodge
37. Falher
38. Manning
39. Lac La Biche
40. Cardston
41. Foremost
42. Czar
43. Castor
44. Eckville
45. Pincher Creek
46. Fairview
47. Lacrete
48. Thorhild
49. Drumheller
50. Medicine Hat
51. High Prairie
52. High River
53. Spirit River
54. Whitecourt
54. Warner
56. Hines Creek
57. Eaglesham
58. Hanna
59. Vulcan
60. Strathmore